Bulletin No. 24 (Revised). *April, 1942.*

UNIVERSITY OF ALBERTA
COLLEGE OF AGRICULTURE

INSECT PESTS OF GRAIN IN ALBERTA

BY

E. H. STRICKLAND
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Insect Pests of Grain in Alberta

BY

E. H. STRICKLAND

Professor of Entomology

Farmers in Alberta are fortunate in that they have to contend with comparatively few insect pests in grain fields. Several of those that do occur in this province are liable, however, to be extremely destructive from time to time.

Certain of these, such as wireworms and wheatstem sawflies cause appreciable losses every year in those districts in which they are well established; others, such as grasshoppers and cutworms, normally are present in too small numbers to cause much concern. Outbreaks of the latter, however, are liable to occur with such intensity over a period of years that the losses they occasion are very great.

With the knowledge we have at the present time we are unable to gain complete control over any of these pests. The habits of all of them are, however, sufficiently well understood for all farmers to be able to reduce the damage that they would otherwise do by following the advice that is given in the following pages. This advice is, to a large extent, the outcome of our own experience, though much of it has been obtained from publications of other workers, particularly those of members of the three Dominion Entomological Laboratories situated in the prairie provinces.

In this bulletin the discussion of each pest must, of necessity, be brief. For this reason, references to more complete information are given at the end of each discussion. The majority of publications can be obtained, free of charge, by writing to the institution which issued them. The publications of the Dominion Division of Entomology can be obtained direct from Ottawa, from the Entomological Laboratory at Lethbridge, or from this University. References to publications that are not readily obtainable are not given.

RECOGNITION OF INSECT PESTS

In order that a farmer may select the most suitable method for avoiding or for reducing insect damage, it is necessary for him to identify the insect that is causing it. In many instances he is more liable to notice the damage to his crops than he is to observe the insect that is responsible for it.

We have, therefore, prepared the following table to assist in the identification of the culprit from the appearance of the damaged plants themselves.

1. Plants fail to appear above ground.

Dig up, and examine a number of grains.

a. Grains complete, but have failed to germinate. Not insect damage.
b. Contents of grain are eaten out. *Large Wireworms* (page 34).
c. Embryos have disappeared. *Small Wireworms* (page 34).

2. Plants above ground, but not yet headed out.

a. Dead plants projecting from soil, blades tightly rolled up and dry. *Wire worms* (page 34).
b. Plants, for greater part, cut off at ground level and lying on surface of the soil. *Cutworms* (page 19).
c. Central shoot of plant turns yellow, later becomes tightly rolled up and dry. *Wireworms* (page 34).
d. Young wheat plants are stunted. Older blades have a bluish tinge and are unusually broad, central shoot withered or missing. *First Generation Hessian Fly* (page 49), or *Wheat Shoot Miner* (page 48).
e. Tips of blades yellow, or turning brown, with reddish spots at about half their length from the base. *False Chinch Bugs* (page 54).
f. Blades irregularly notched along their edges or entirely eaten. Probably *Grasshoppers* (page 11), sometimes *Cutworms* (page 19).

3. Heads formed but grain not ripening.

a. Wheat straw bent over near base and head again turning upwards so that each straw is an N shape. This is *not* Hessian Fly or any other insect damage. Probably due to very rapid growth followed by heavy winds.
b. Wheat, barley or rye straws bend over at 2nd or 3rd node but head does *not* turn upwards; it is usually prevented from reaching the ground by the blades of neighboring plants. *Second Generation Hessian Fly* (page 49).
c. Scattered ears of wheat throughout field have turned white, remainder of plant apparently healthy.
Pull out head, with straw, from leaf sheath. If the straw breaks off straight across at the point where it turns white this probably is *not* insect damage. The cause is not known, though it is claimed that very severe feeding by *Says' Grain Bug* (page 52) may sometimes produce similar results. If the straw is irregularly chewed at the base it is *Wheat Stem Maggot* (page 47).
d. Heads covered with greenish or orange coloured plant-lice. Most common on oats. *Grain Aphis* (page 55).
e. Many flowers at base of head are "blind," i.e., no grain formed and turn white prematurely. Most common on oats. "Blind" oats may be produced by a variety of different causes, other than insects. When confined to bases of heads often due to *Thrips* (page 53).

4. Heads ripening or fully ripe.

a. Wheat stems cut from plants close to ground. *Wheatstem Sawfly* (page 43).
b. Wheat heads cut from plants and fall to ground. *Grasshoppers* (page 11).
c. Wheat, barley or rye straws bent over at 2nd or 3rd node from the ground and lying against neighbouring plants. This, superficially, resembles a rather light hail damage. *Second Generation Hessian Fly* (page 49).
d. Oats. Individual oats cut from heads and scattered on ground. *Grasshoppers* (page 11).
e. Rye. Exposed half of grains eaten. *Grasshoppers* (page 11).
f. Wheat heads, and more rarely barley heads, may be a little pale in colour, more often appear to be quite normal but, on close examination, are found to contain little or no grain. *Say's Grain Bug* (page 52).
g. Small lace-like cocoons containing a brown-striped caterpillar or small white chrysalis fastened to heads of wheat. *Diamond Backed Moth* (page 57).

TABLE FOR THE RECOGNITION OF INSECTS MOST COMMONLY FOUND IN GRAIN FIELDS IN ALBERTA

1. **More or less worm-like insects** which may or may not have legs. Found upon or below the surface of the soil.
   a. *Cutworms*, i.e., smooth skinned caterpillars, up to about 1½" long. Usually found below the soil surface. *See Cutworms* (page 19) for a table for the identification of common species.
   b. *Dull brown* cutworm-like insects with wrinkled skins and apparently no heads or legs. Not very active.
      (1) Never more than ½" long. Body covered with fleshy spurs somewhat resembling rose thorns. Sometimes very numerous in the spring. *March flies* (page 55).
      (2) Up to 1¼" long. No fleshy spurs on body. *Leather jackets* (page 55).
   c. *Orange* coloured shining grubs with very tough skins. Up to 1" in length. Always found below ground.
      (1) Not very active when disturbed. Usually rather flattened and with two blunt claws at the hind end of body. *Wireworms* (page 34).
      (2) Extremely active when disturbed. Body cylindrical and always pointed at hind end. *False wireworms* (page 41).
   d. *White "worms"* which are very slender, with no legs; up to 1" long; extremely active when disturbed. These are the larvae of a fly. They feed on other insects. Beneficial. *Therevid larvae.*
   e. *White grubs* with brown heads and well developed legs. Do not curl up when disturbed; run rapidly. Usually about ½" long. These feed mainly on very young wireworms, cutworms and grasshopper eggs. Beneficial. *Ground beetle larvae.*
   f. *Black grubs*, up to 1" long. Well developed legs, run rapidly. Feed on cutworms and wireworms. Very beneficial. *Cutworm lions* (page 22).
   g. *Greyish white grubs*, about ¼" long by the middle of June, body always bent in C shape so that its hind end lies under the head. Look somewhat like small cutworms. Quite harmless, often numerous in fields which have been manured. *Dung-beetle larvae.*

2. **Moths.**
   a. Brown-black or grey moths, about 1" long, which are very common in houses throughout the summer. Most of these are *Army cutworm moths* (page 31). *Glassy cutworm moths* (page 33), or the moths of other cutworms which are not very injurious to grain. The greenish moths of the *Pale Western cutworm* (page 27), and the reddish or yellow moths of the *Red-backed cutworm* (page 29) do not often enter houses. They may be very abundant in the fields, but do not attract much attention since they fly chiefly after dark.
   b. Small light grey moths, about ⅜" long, often fly in clouds around flowering weeds and around lights at night. *Beet webworms* (page 56).

3. **Beetles.**
   a. Small black or brown beetles which run very quickly, and hide under stones, etc. Nearly all feed on other insects and are beneficial. *Ground beetles.* (Illustration on page 34).
   b. Small black beetles, about ½" long. Walk rather slowly. More slender than ground beetles, and with a distinct furrow across the middle of their backs. If placed up-side-down on a *smooth* surface they soon jump into the air with an audible "click". No other beetle does this. *Wireworm beetles* (page 34).
   c. Large black beetles, sometimes with metallic red or green spots on wing covers, about 1" long. Long legs, run *very* quickly. *Fiery hunters* (page 22).

d. Large black beetles, up to 1" long. Walk very clumsily, and stand on their heads if mildly alarmed. Often seen in gopher holes. *False wireworm beetles* (page 41).

4. Grasshoppers and Crickets.

There are about 70 different kinds of grasshoppers in Alberta. Of these not more than three are liable to be very injurious to grain fields. See Grasshoppers (page 11) for tables for the identification of immature hoppers, grasshoppers and crickets.

5. Flying insects other than moths, beetles or grasshoppers.

a. Small black-and-yellow, slender wasp-like insects, about ¼" long. Usually rest head downwards on wheat stems. Seen only in May and June. *Wheatstem Sawfly* (page 43).

b. Rather large but slender black wasps with black wings, about 1" long. Very active; run on ground or make short flights. Capture, and eventually destroy, half to full-grown cutworms. Beneficial. *Solitary wasps* (page 22).

6. Eggs, pupae or cocoons turned up with the plough.

a. Covered with, or entirely composed of, earth.

(1) Hard, less than an inch long, somewhat resemble gopher droppings. When broken open seen to contain yellow eggs. *Grasshopper eggs* (page 11).

(2) Hard, about 1½" long, roughly oval, composed entirely of earth. Usually found with one end open and empty. *Cutworm pupation cells* (page 27).

(3) Soft, about 1" long, narrow, elongate, somewhat resemble pieces of decaying sticks. When pulled apart seen to be composed of silk. May contain small caterpillar or pupa. *Beet webworms cocoons* (page 36).

b. Reddish brown, hard shelled, chrysalis, less than an inch long. Hind end ringed and movable. *Cutworm pupa* (page 27).

c. White, delicate skinned pupa, with very soft wings and legs all pointing backwards and lying on the underside of the body. Beetle pupa, probably of *Ground beetle, Wireworm or False Wireworm.*

d. Hard-shelled, dark brown oval structure with a perfectly smooth surface. Usually open at one end and empty.

(1) About ¼" long. Similar objects abundant in dead animals. *Pupa of a Fly.* Probably a cutworm parasite.

(2) About 1" long, appears to be composed of many very thin sheets of a material that has metallic reflections. *Cocoons of Solitary Wasp* (page 22).

e. Yellow eggs resembling small grains of wheat. Most abundant just below soil surface in sod. Seen only in early spring. Eggs of *Roadside Grasshopper* (page 15), which have swollen during the winter and have broken from the earth-covered egg mass in which they were laid.

RELATION BETWEEN THE LIFE-HISTORY OF INSECTS AND CONTROL MEASURES

Nearly all insects change in their appearance, and often in their feeding habits to a greater or less extent, between the time when they hatch in a wingless condition from their eggs and that in which they are fully developed flying insects.

A recently hatched "hopper" is, however, sufficiently similar in appearance to a mature flying grasshopper for anyone to recognize it as being the same insect. Whenever the change in appearance is no greater than this the insect can be *active* throughout its life and its *feeding habits* do

not change from the time it hatches till it dies. For this reason *we can usually employ the same control measures for these insects throughout their lives.*

A caterpillar or cutworm, on the other hand, is so totally different from the moth into which it will develop that no one, who did not already know it, could tell that it really is a young moth.

So great is the difference in structure between the caterpillar and the moth that the insect cannot change from the one to the other without becoming *inactive*, as a pupa, while the change is taking place. Not only does the structure change completely, but so, also, do the *feeding habits*. The cutworm eats solid food, such as leaves, while the moth can suck up fluids only, and feeds on nectar from flowers.

We cannot, therefore, employ the same control methods throughout the life of the insect. In certain cases it is much easier to control such insects in a stage in which they may be doing us no damage whatever than it is in the stage in which they are serious pests.

CONTROL MEASURES WHICH CAN BE EMPLOYED BY [illegible]

Spraying and Dusting.

Generally speaking, grain producers will rarely find it to be practical to employ poisoned sprays or dusts for the control of insect pests. The areas devoted to their crops are too large, and the intrinsic value of their produce is not sufficiently great to warrant the expense that this would entail.

We must, therefore, look for less expensive measures, even though they may not be quite as effective.

Use of Poisons.

The most practical method whereby insects in grain crops can be poisoned is by employing poisoned baits. These are of great value in connection with the control of grasshoppers and of certain cutworms, but they cannot be satisfactorily employed for other insect pests.

Constant efforts have been made to find materials which can be applied to, or drilled in with, the seed in order to protect it from insects such as wireworms. None has been found that can be employed in this manner except at prohibitive costs.

Cultural Practices.

Since the majority of grain pests live, for at least a part of their lives, below ground, it is often possible to reduce their numbers or the damage that they can do, by modifying the usual cultural practices which are employed in the district. Several such modifications will be discussed in this bulletin in connection with various insect pests. When they can be employed without seriously upsetting the routine of the year or resulting in danger of soil drifting, loss of moisture, etc., they should always receive very careful attention. These modifications entail no additional expense and may greatly reduce losses from insect pests.

It should be borne in mind also that vigorous plants, as a rule, suffer less from insect damage than do those which are making a poor growth. For this reason, rapid growth should be encouraged at all times. In the case of certain insects, such as wireworms, the application of fertilizers, particularly phosphates, in order to counteract soil deficiencies in these materials may so stimulate the plants that they have a marked effect in reducing insect damage.

Rotation and Trap Crops.

The principle of rotations, as applied to insect pests, is to avoid growing the same crop year after year in the same field, since this gives the insects that normally feed upon it an opportunity to increase in numbers.

Under existing conditions there is little scope for practising rotations on grain-producing farms. In districts which are infested with the wheatstem sawfly it will, however, be seen that resowing wheat with some other non-susceptible crop or with summerfallow, is practically a *necessity* during years of sawfly abundance. In order to be fully effective, such rotations must be practised in conjunction with trap crops to arrest the spread of the egg-laying females.

CULTURAL PROGRAMME ADAPTED TO THE REDUCTION OF [illegible]

Shallow Fall Cultivation of Stubble.

It is obvious that, on the open prairie and hardly to a less extent elsewhere, the only places where the majority of grain infesting insects can pass the winter are either on the *surface* of the soil, whether protected or otherwise by trash, or *below ground*. Farmers, therefore, have an excellent opportunity to reduce these numbers by disturbing the top few inches of the soil before freeze-up, since by so doing they can greatly increase the winter mortality of those which normally hibernate here in a resting stage.

Shallow fall cultivation of stubble, in which an effort is made to bring all of the stubs to the surface and to leave them lying there, is the safest method for reducing many pests, such as grasshoppers (egg destruction), sawflies (larval destruction), webworms (pupal destruction), shoot maggots, etc., which hibernate as pupae just beneath the soil surface. For many pests, the earlier the cultivation can be accomplished after harvest the heavier will be the mortality.

Deep fall ploughing, though it may bury the eggs of cutworms, etc., deeply in the soil, is not very valuable. It tends to give certain pests added protection from winter temperatures and it may increase their survival. It is doubtful, also, whether deep spring ploughing has much effect in the control of insect pests. Even when it is followed by a packer, the soil will rarely be sufficiently compressed to imprison any insects which are turned under.

Summer Fallowing.

A perfectly clean summer-fallow, particularly from mid-June to mid-July, will destroy many insects which would have matured on volunteer

grain or weeds. Until early in June, this volunteer growth may serve as a rather useful trap-crop in attracting insects, such as Sawflies and Hessian Flies for egg-laying. These can, then, be destroyed, with the growth, by late June summerfallowing. It is recommended that, during this period, *repeated shallow cultivation* replace any deep ploughing. Such cultivation will not loosen up the soil, thus allowing deep egg-laying by wireworm beetles; it should encourage the germination, and allow for the destruction of all shallowly placed weed seeds, and will avoid burying deeply resistant weed seeds which will only cause trouble in future years.

If deeper ploughing is, at any time, necessary it is suggested that this be done, in so far as is possible, during the latter half of July. This should accomplish the following:—

1. Destruction of nearly all of the pupating wireworms in the field.
2. Assure that there will be no vegetation of a sufficient size to attract Red Backed Cutworm moths for egg-laying during August.
3. Give time for a crust to form on the surface before Pale Western Cutworm moths begin egg-laying.
4. Assure that no grasshoppers will lay their eggs in the field.
5. Destroy the majority of any cutworm pupae which may be in the field.
6. In all probability, prevent any annual weeds maturing and producing seed before freeze-up.

If it is not *necessary* to plough at this time, it is suggested that the final cultivation during the latter half of July be about an inch deeper than that employed earlier, in order to destroy wireworm pupae.

[illegible]

As has already been pointed out, there are about 70 different kinds of grasshoppers in Alberta. The majority of these are not a menace to grain producers since they feed almost exclusively on native grasses and weeds. Several of them are, as a matter of fact, more beneficial than otherwise. They harbour important parasites of the injurious species at seasons of the year when the latter are not available for them.

There are, however, three species that are liable to be extremely destructive to grain when they are present in abnormally large numbers. Outbreaks of these grasshoppers as a rule take a number of years to develop, and they could often be checked from the start if *everyone* in the threatened territory noticed the gradual increase in numbers and immediately took the proper steps to reduce them.

For this reason, and also in order that money and labour will not be wasted in an attempt to reduce the numbers of the harmless species, it is very important that everyone is able to recognize the injurious grasshoppers in all stages of their development.

TABLE FOR THE RECOGNITION OF COMMON GRASSHOPPERS AND CRICKETS IN ALBERTA

1. Small wingless 'hoppers, only partly grown. (All *injurious* grasshoppers are in this stage of development only late in May and throughout June.)
   a. Mainly *black* but with strongly contrasting white marks on body and legs. Usually found in sod around grain fields or in small pastures. *Roadside Grasshopper* (page 15)
   b. Very small *dull brown*, with well-marked light and dark square areas along the top of the jumping hind legs. *Young Lesser Migratory Grasshopper* (page 16)
   c. Half-grown 'hoppers. Bright *yellow-and-black*, with fine black lines on yellow wing-cases. Most abundant in recently deserted fields, in or around stubble with a dense growth of weeds. Partly developed *Lesser Migratory Grasshopper* (page 16)
   d. Bright *green*. Most abundant in fall rye or weedy areas. *Two-striped Grasshopper* (page 16)
   e. Light grey, more slender than usual. Often found in sod at a distance from cultivated land. These are *harmless* to grain.
2. Full-grown grasshoppers and crickets.
   a. Coloured hind wings; red-and-black, or yellow-and-black. All of these are practically *harmless* to grain.
   b. Transparent hind wings.
      (1) About 1¾" long. Mottled brown or yellow; with large dark marks on front wings, and two rather faint yellowish stripes forming a long V on body. Eyes round. *Roadside Grasshopper* (page 15)
      (2) About 1¾" long. Nearly uniform brown without very definite marks on front wings. Eyes about twice as long as wide. *Lesser Migratory Grasshopper* (page 16)
      (3) About 1½-2" long. Dull greenish yellow. Front wings about the same colour as body with the exception of two conspicuous straw-yellow stripes forming a long V along the top of the body. Eyes about twice as long as wide. *Two-striped Grasshopper* (page 16)
   c. Wingless. About 1½-2" long, much stouter than an ordinary grasshopper. Female with a sword-like ovipositor that is nearly as long as the rest of the body. Most abundant in the foothills. *Mormon Cricket* (page 18)
   d. Black crickets, about 1" long, incapable of flight, but with short wings. *Field Cricket* (page 18)

Habits of Injurious Grasshoppers.

All injurious grasshoppers lay their eggs in the soil. The females dig holes in the ground and fill them with about 25, or in some cases with about 50, eggs. These are surrounded with a gummy substance that hardens and sticks the eggs together. When dug up these "egg-masses" somewhat resemble gopher droppings until they are broken open to expose the elongate light yellow eggs.

Though the eggs are all laid in the fall they do not hatch till about the end of the following May.

The small wingless 'hoppers, when they hatch, feed continually on vegetation and gradually increase in size until early in July, when most of them are full-grown and are able to fly. They then become much scattered throughout grain fields that may have been free from 'hoppers earlier in the year.

'Hoppers grow by a process of moulting; they shed their "skins" periodically. Whenever 'hoppers are numerous these cast empty skins will be found in large numbers. They must not be confused with dead 'hoppers.

The flying grasshoppers continue to feed. They begin to lay their eggs about the end of July and continue to do so until they are killed by frosts in the fall.

Causes of Grasshopper Outbreaks.

A variety of climatic conditions produce grasshopper outbreaks. Generally speaking, a succession of dry hot years with open falls results in an increase in the number of grasshoppers. Timely rains, with cold, overcast weather in the latter part of May, may kill a great many of the young 'hoppers, but a wet season cannot be relied upon to terminate an outbreak.

Termination of Outbreaks.

One of the most important factors that terminate outbreaks is the gradual increase of their natural enemies, other insects that are parasitic upon them. In the early stages of an outbreak the proportion of parasites to grasshoppers is very small. It usually takes them several years in which to re-establish their numbers at the expense of the grasshoppers. If, during these years, we can destroy a large number of the grasshoppers with baits or by any other means, we hold their numbers more closely to the proper proportion with the parasites and hasten the year in which the latter will again be able to keep them under control.

Control Measures.

1. Cultural.

No eggs are ever laid in well-worked summerfallow land. Such fields will be free from 'hoppers in the early spring, but they may later be infested by migrations from elsewhere.

Since many eggs (Lesser Migratory and Two-striped Grasshoppers) are laid in weedy stubble, this should either be lightly cultivated in the early fall to expose the eggs, or deeply ploughed later in the fall or in the spring. Packing after spring ploughing is advisable.

2. Use of Fire.

Note, particularly, recommendations given in discussion of each species, for killing young 'hoppers with fire. Baits, as described below, should be employed *only* where it has been found to be impractical to destroy the 'hoppers with cultural methods or by the use of fire.

3. Baits.

The most economical bait which can be made with readily procurable materials is:

Bran and Sawdust (half and half)	100 lbs.
White Arsenic (or Paris Green)	5 lbs.
Water	10-12 gals.

When no sawdust is available 100 lbs. of bran can be used. The sawdust is added simply to improve the scattering quality of the bran and is of little value as stuff. The ratio of sawdust to bran should never exceed 2:1.

Very rarely, the addition of one gallon of molasses to the above formula may somewhat improve its killing effect. This increases costs to such an extent that it cannot be recommended as a general practice.

Numerous experiments upon the value of replacing the water in bait with oil have indicated that, under Albertan conditions, oil baits are *less* effective than are water baits when the latter are properly applied for the control of young hoppers which are still more or less crowded together in breeding areas. The only conditions which may warrant the greatly increased expense of employing oil baits is in connection with the control of flying grasshoppers which are moving rapidly from field to field in late summer.

It is suggested that the greatest returns from money expended can be obtained if municipalities supply only the standard ingredients for water-prepared baits, but that, should any farmer desire molasses or oil, he obtain these materials himself or pay the municipality their cost price, and have them mixed at the station into such bait as he may require.

Note—Liquid Sodium Arsenite, or Sodium Fluoarsenate are now largely used to replace White Arsenic at Government mixing stations. The latter has marked advantages over any arsenical poison. Though it kills grasshoppers more rapidly it is less poisonous to stock. It cannot, however, be readily obtained by individuals who wish to prepare small quantities of bait in districts in which no Government mixing stations have been established.

Mixing poisoned baits. Where no mixing station has been established bait can be mixed by hand.

Spread the bran and sawdust on the floor of a barn or other building from which stock can be excluded. Scatter the arsenic over this and mix in thoroughly by turning over with a hoe or shovel. Be careful not to allow the arsenic to fly in the air. It may cause skin burning, and is dangerous if inhaled. Dissolve the molasses, when this is employed, in about half of the water you think you will require, and stir it into the bait. When liquid arsenic is employed this is mixed with the water before it is added to the bait. Continue to add water a little at a time, mix the bait in as wet as you can make it without being able to squeeze water out of a handful. The bait is now ready for immediate use, but it can be bagged and stored for two or three days if desired.

Application of bait. Never scatter bait anywhere where grasshoppers are not numerous, as soon as it is dry it loses most of its attractions for them.

Never apply bait on a cool, windy or rainy day. At the time when the bait is spread the air temperature must be at least 68° F. and the best results will be obtained if there are prospects that this temperature will continue to rise. If, however, the temperature of the surface of the soil is nearly

100°F., grasshoppers feed very little and the bait will dry out so rapidly that few of them may eat any of it before it ceases to be attractive to them.

When temperature conditions are satisfactory, broadcast bait between the hours of 7 and 10 a.m. At this time grasshoppers are doing most of their feeding, and the bait remains moist for the longest time.

Throw the bait as far from you as you can. One poisoned flake will kill several small grasshoppers. The more scattered these flakes are the better will be the killing.

Ten pounds of prepared bait is ample for an acre. All bait used in excess of this is wasted.

In certain seasons, practically all of the grasshoppers in any one field will hatch within two or three days and it will be noticed that they are all of about the same size. When this is the case, one well-scattered application of bait should effect a satisfactory control. Unfortunately, in some years, hatching is very irregular and it may extend over several weeks. In such years, grasshoppers of several sizes will be found in the field. It may be wise to delay scattering any bait until very small ones are no longer seen. This will reduce the danger of having to repeat the poisoning.

Danger to stock. Properly scattered, bait is absolutely harmless to stock. When stock are killed it is *always* due to improper handling of bait. Never leave bait in *bulk* where stock can get at it. *Bury* any bait that is not used (burning will not destroy arsenic). Don't use bags for feed if they have contained bait and do not leave them where stock can lick them. If baiting pastures, see that the stock are well supplied with salt, and be sure you scatter the bait thoroughly.

4. Hopper Dozers.

These mechanical grasshopper catchers are so inferior to bait that they are of no practical value under Albertan conditions.

ROADSIDE GRASSHOPPERS (Camnula pellucida)

FIG. 1.—Roadside Grasshopper:—A. Egg masses, one broken open to show eggs; B. Young hopper, soon after hatching (much enlarged); C. Full-grown grasshopper laying eggs. All except B are natural size. (Original.)

Distribution. Entire province. Most abundant in southern half and in Peace River District. Usually found in largest numbers where soil is rather heavy.

Life-history. The eggs are nearly always laid in *unbroken sod* The females collect into well-defined breeding areas, in which practically all of them lay their eggs During outbreaks eggs may be very abundant in the *sod* around grain fields. Even here they will be found only in well defined breeding areas, possibly of only a few rods in length.

When the small black-and-white 'hoppers hatch they may at once spread into the edges of the grain field by day, but for about the first two weeks of their life they return at night to the sod where they hatched. A little later they spread throughout the entire fields. When half-grown they are almost completely black, and are more "chunky" in build than are most grasshoppers.

Special Control Measures.

Burning over sod Since, for about two weeks at the end of May or early in June, roadside 'hoppers collect in the sod around fields every night, nearly all of them can be killed by scattering a little straw here and burning it off after dark The only precaution to take is to be sure that all of the 'hoppers have hatched Fire will not destroy the buried eggs. Nearly all 'hoppers will have hatched within three days of the time that the first were seen.

Bait The best results will be obtained by using bait *early in the season* while the 'hoppers are still crowded together in the breeding areas. In mid-summer, when they are already scattered, baiting is of far less value In late summer, however, when the grasshoppers are again collecting into their breeding areas, these areas can be baited with excellent results.

LESSER MIGRATORY GRASSHOPPER (Melanoplus mexicanus). TWO-STRIPED GRASSHOPPER (Melanoplus bivittatus).

FIG. 2—A Lesser Migratory Grasshopper; B. Two-striped Grasshopper Both natural size. (Original.)

The habits of these two grasshoppers are sufficiently similar that, for all practical purposes, the control measures for them are the same.

Distribution. Entire province, but most abundant in districts in which the soil tends to be light.

Life-history. Eggs usually laid in deserted fields and in weedy crops. Since these eggs are scattered throughout such fields, the control of these species is far more difficult than is that of the Roadside grasshopper

Special Control Measures

Burning weeds When a field, in which there is a dense growth of weeds, such as Russian thistle or mustard, is found to be heavily infested with 'hoppers, it should be burned over shortly after all of the 'hoppers have hatched. This can often be accomplished with the aid of harrows, etc., when a good burn cannot be otherwise obtained. The hotter the day, as a general rule, the more complete will be the burn. For these 'hoppers there is no advantage in burning at night.

In this connection it should be remembered that it is on such fields that the increase in the number of grasshoppers takes place. They are the source of infestation of grain fields later in the season, and it is far more difficult to kill grasshoppers in grain fields with bait than it is to destroy them with fire among weeds.

Summerfallowing Land that is being summerfallowed, and which is found to be heavily infested with 'hoppers, should be ploughed from the outside towards the centre. This crowds the 'hoppers together on to the unploughed portion, which should be treated with bait and left for two days before ploughing is completed. A modification of this is to plough the field in "strips," after ploughing a barrier of about a rod wide right round the field, and to bait the unploughed centre of each strip two days before turning it under. When this is not done all of the 'hoppers that were in the field will be driven into neighbouring grain.

Bait Bait can be broadcast in uncultivated fields which cannot be burned over in early summer. This will destroy a large percentage of the 'hoppers.

When flying grasshoppers have entered and scattered throughout a grain field, bait should be broadcast in strips, about two rods apart, throughout the field. Since flying grasshoppers are very active, most of them will find and feed on the bait before it has dried out. This reduces the cost and labour of baiting by about half. For baiting in this manner it is probable that the employment of oil baits is justified, despite their additional cost.

Summary of Important Points to be Remembered in Control.

1 Cultivate *shallowly* every field in which grasshoppers are numerous, *immediately* after harvest. The "trash mulch" thus produced reduces soil drifting, no more eggs will be laid and over half of those already laid will be destroyed. Fields so treated will be practically free from grasshoppers (and wheat-stem sawfly infestation will be reduced) in the following spring.

2 Burn over dried vegetation in which 'hoppers are numerous in the spring. Be sure that the 'hoppers have all hatched before so doing. This is the cheapest, and most thorough way to kill grasshoppers and it does so before they have done any damage. Farmers will do *themselves* more good by burning over badly infested vacant land two or three miles from their own fields than they will by scattering bait on lightly infested crops. Remember that every grasshopper on vacant land will fly to neighbouring grain fields later in the season.

3. Everyone should realize that it is not strictly honourable, when there is a free distribution of bait, to fail to take advantage of every other method of destroying grasshoppers before he applies for bait. This should be considered as a *last resort*, to be employed only when cultural methods and burning have been impossible, or they have failed to give satisfactory results.

4. *Never* apply more than seven to ten pounds to the acre. Scatter well and you will kill *more* grasshoppers than would be possible with a heavier application of bait.

References to Literature on Grasshoppers.

Criddle, N., "Grasshopper control in Canada East of the Rocky Mountains," Division of Entomology. Ottawa. D. of A. Entom., Bull. 31, 1931.

Strickland, E. H., "Control of Grasshoppers in Alberta," 1922, and "Recommendation for Grasshopper Control in Alberta, 1932." Department of Agriculture, Edmonton.

MORMON CRICKET (Anabrus simplex)

FIG. 3—A. Female Mormon Cricket (The male has no ovipositor, and is smaller), B. Female Field Cricket. Both natural size (Original.)

Distribution. This large wingless insect does not often attract attention in Alberta, though it is liable to occur in destructive numbers in the southwest portion of our province in seasons which have been favourable to its increase.

Life-history. The eggs, unlike those of grasshoppers, are laid singly in the soil. Early in the summer the young crickets eat plants completely. Later, when the heads are formed, they may climb up to the heads and eat out the developing grain. They do this most freely in the evening. These crickets, however, feed freely on grasshoppers and, when they are not very abundant, may be more beneficial than otherwise.

Control. In parts of Montana, where these insects are liable to be more numerous than we have ever known them to be in Alberta, they sometimes move across country in dense armies. Under these conditions, dusting with sodium arsenite has proved to be an excellent control measure. Here we have not experienced such migrations, but have had good success with grasshopper bait in destroying those that are feeding on grain.

FIELD CRICKET (Gryllus assimilis).

Distribution. Throughout the province.

Life-history The eggs are laid in the soil singly. They do not hatch till about the beginning of July, and, since the young crickets are unable to climb plants, they do no appreciable damage to growing grain. They are mature at about harvest-time. During the hottest part of the day they inhabit cracks in the soil and come out to feed only at night or on cloudy days. Unfortunately they are very fond of eating binder-twine, and, if sheaves are left lying for some time in fields in which the crickets are numerous, many of the bands may be cut by them.

Control Twine that has been treated by the manufacturers to protect it from crickets or field mice will not be damaged. Untreated twine can be protected by soaking for half-an-hour in a solution of 1 lb. of Bluestone in 6 gals. of water Thoroughly dry and pound the balls with a stick when dry to loosen them up and to avoid knotter trouble.

In a field in which crickets are seen to be numerous, stook as soon after cutting as possible.

CUTWORMS.

There are over 200 different kinds of cutworms in Alberta. Only about 30 of them ever feed on grain. Fortunately, the great majority of these occur, every year, in such small numbers that the damage any of them do is negligible.

A few species, however, increase in numbers very rapidly when climatic conditions are favourable to them, and during these years of cutworm "outbreaks" they are liable to be extremely destructive to grain crops.

The habits of those species that have caused the greatest damage in Alberta have been carefully studied, but those of the less common ones are not, in the majority of cases, very well known.

Unfortunately, it is possible that certain climatic conditions or modifications in cultural practices may, at some future date, permit outbreaks of these less common species.

TABLE FOR THE RECOGNITION OF CUTWORMS MOST FREQUENTLY SEEN IN GRAIN FIELDS.

1. General colour light grey, with few body markings.
   - a. Head straw-yellow with a blackish $\wedge$ or X on the front of it. Never seen before about the middle of May, when they are less than ½" long. Full-grown and about 1½" long by middle of June. *Pale Western Cutworm* (page 27)
   - b. Head bright orange-red, with no markings on it Body shining and semi-transparent, with a dark internal stripe along its upper side. Seen as soon as the frost is out of the ground when they may be already nearly 1½" long. *Glassy Cutworm* (page 33)
   - c. Head mottled brown. Body with a number of small black spots. Seen as soon as the frost is out of the ground, when they may be nearly 1¾" long. *Early Cutworm* (page 33)

2 *General colour dark green or reddish.*

a With a distinct broad red band along the entire length of the body. Sides of body may be dark green or creamy yellow. Not seen before about the middle of May when they are less than ¼" long. Full-grown and about 1½" long by middle of June. *Red-backed Cutworm* (page 29)

b Usually dark olive-green all over, sometimes with two rows of poorly defined cream spots, or with a dull yellowish brown band along the top of the body. Seen as soon as the frost is out of the ground, when they are ½" to 1" long. Full-grown and about 1½" long by the end of May. *Army Cutworm* (page 31)

Methods for ascertaining rapidly whether unrecognized cutworms are liable to be destructive to grain, and the best control measures to adopt.

Should a farmer, at any time, find that his fields are heavily infested with a cutworm that he is unable to recognize, he can very quickly find out enough about its habits to decide upon the best immediate steps to take by the following procedure:

1 Note their average size. If they are already nearly 1½" long there is not much cause for alarm. They are practically through feeding for the year and will disappear in a few days time.

2 If they are smaller observe, in the field, on what they are feeding or have fed. If only on broad-leaved plants, such as weeds, they are in all probability harmless to grain. If, however, they feed on grain or volunteer grain they are liable to be destructive. When there is too little variety of growth in the field for their food choice to be ascertained, collect a few and place them in two beakers. To one beaker add a few leaves of weeds, such as dandelion, or some alfalfa and some blades of grain. To the other add only blades of grain. By observing what they have eaten on the following morning, you will know whether they prefer broad-leaved plants or grain, and also whether they will eat the latter when there is nothing else available.

3 If they eat grain observe, in the field, whether most of their feeding is done from *above* or from *below* ground. If they feed above ground it is probable that bait, broadcast as recommended on page 24, will control them. When, however, it is seen that the plants have been attacked below the ground level it is very unlikely that bait will prove to be effective.

4 Observe whether the cutworms are above ground by day. If so, and the majority of them are crawling in the same direction, bait can be applied in furrows ploughed across their line of march (see page 24). This will greatly reduce the amount of bait that is required to control them.

A word of caution is necessary. The habits of cutworms vary considerably with temperature and with soil moisture. On cold days or nights they feed very little and tend to stay below ground. When the soil is dry at the surface several inches remain below ground and feed extensively there, even though they move and feed freely on the surface when the soil is damp.

One should, therefore, repeat field observations under as many climatic conditions as possible. In the meantime, if there is any doubt as to

these habits, send a few specimens to the University or to Lethbridge for determination and advice.

Habits of all Injurious Cutworms.

Egg laying habits of moths. In so far as is known all of the moths of cutworms that are liable to be injurious to grain in Alberta lay their eggs exclusively *in the soil* and never on weeds or other vegetation. This is not true for all kinds of cutworms, but it certainly applies to those grain feeders which have been studied in detail.

As a general rule, the moths lay their eggs only where it is easy for them to place them *beneath the surface of the soil*. The eggs are laid in August or September, but those of the majority of species do not hatch till the following spring. This necessitates some protection. The moths, however, are not provided with powerful organs for digging into the soil, as are grasshoppers. They are forced, therefore, to lay their eggs in fields in which either they can get under loose clods of earth, or there is a sufficiently loose layer of earth on the surface for them to be able to rub small holes with the end of their soft bodies in it, in order to place their eggs below ground.

Egg laying is usually accomplished just before sundown, or after dark and, for this reason, is not often observed.

Habits of cutworms. Cutworms which hatch from their eggs in the fall feed freely on weeds till freeze-up, when they burrow just beneath the soil surface and remain inactive till the following spring. Those which do not hatch till the spring usually do so soon after the crop has been seeded. The newly-hatched cutworms all come above ground and climb up the plants, where they feed on the upper side of the blades, or else bore irregular notches in their margins. After a few days, however, they re-enter the soil and, depending on what species of cutworm they are, they either remain continually below ground and feed on the underground parts of the plants or they come above ground to feed and retire into the soil when they have finished. As a general rule, all of them remain below ground for the greater part of the day, and are most active at night time.

Pupation. When a cutworm is about 1 ," long it is full-grown. It now ceases to feed, burrows down to form earth and there makes a small cavity in the soil. In this it turns to a reddish pupa, or "chrysalis," from which, at about the end of a month, the moth escapes and works its way to the surface of the soil.

Habits of the moths. Cutworm moths feed only on nectar from flowers. They are most active at night-time, and many species are strongly "attracted" to lights. These are frequently a serious nuisance in houses. They are harmless to grain except in so far as they lay the eggs from which will come next year's crop of cutworms.

Causes of Cutworm Outbreaks.

Generally speaking, injurious cutworms increase in numbers when rainfall has been below the average in May and in June. Two dry seasons

in succession are, as a rule, necessary before a serious outbreak occurs. This is due to the fact that, with ample rainfall during these months, both parasites and diseases are capable of destroying so many of the cutworms that they are kept down to small numbers. Dry seasons hamper the effectiveness of both of them.

Termination of Cutworm Outbreaks.

It is commonly believed in many quarters that rain kills cutworms directly. This is, however, not the case. Rain greatly reduces their feeding activities for as long as the soil remains moist. It also strengthens the plants, allowing many that have been only slightly damaged to recover. Rain in May and June does greatly reduce the number of cutworms that will be in the district in the *following year*, because it allows parasites and disease to destroy more of them before they develop into egg-laying moths. On page 28 will be found Mr. Seamans' formula for forecasting the abundance of Pale Western Cutworms from records of wet days in May and June.

Important Enemies of Cutworms which are often observed.

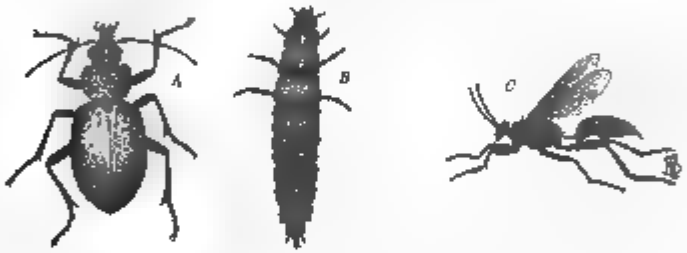

FIG. 4—Enemies of cutworms that are frequently seen in grain fields: A, Fiery Hunter Ground-beetle; B, Cutworm Lion, which is the larva of A; C, Solitary wasp. All natural size. (Original.)

Fiery-hunter Ground Beetle. These beetles occur over the entire province. There are several species, all of which are, for the greater part, black in colour. Some of them have rows of small metallic red or greenish pits on the wing-covers. They are about 1" long. They run *very* rapidly over the soil and occasionally dig energetically into it with their long legs. When so doing they are hunting for cutworms upon which they feed.

These beetles must not be confused with the rather more slender, slow moving and clumsy black beetles that are common in the southern part of the province. These are the adults of False wireworms (see page 41).

The beetles lay eggs in the soil during the spring. Elongate black grubs hatch from these and grow rapidly till they also are about 1" long. These grubs are called "Cutworm lions," since they feed entirely on cutworms. They never come above ground.

The number of the beetles and of their grubs that survive from year to year is entirely dependent upon the abundance of cutworms. Their numbers cannot be increased by breeding and liberating them.

Solitary Wasp During the season of cutworm activity these large slender black insects, with four smoky black wings, search the ground actively for cutworms. They dig energetically with their long legs when they find a cutworm below ground and soon unearth it. They immediately sting it in such a manner that it will be completely paralyzed, but not killed. Now they drag it to a small hole in the ground in which they bury it and lay an egg on it. From the egg a small white grub hatches which eats the helpless cutworm.

Parasites of Cutworms The most important parasites of cutworms are reddish wasp-like insects, and bristly flies which somewhat resemble common blow-flies. Although they are of more importance in killing cutworms than are fiery hunters and solitary wasps, they are less often observed by farmers.

Control Measures.

1. Cultural.

Since all of our injurious cutworm moths lay their eggs only in loose earth, summerfallow should never be worked while the moths are flying. The dates of egg-laying differ slightly with the various species, but the majority of moths are laying eggs throughout August and September.

For this reason fallow land, generally speaking, should be *well worked* and be quite *free from weeds* by the end of July. It need not, then, be touched again during the season. Any subsequent growth of weeds will not mature seed, neither will it remove much moisture from the soil. If desired, however, cultivation can be resumed after the end of September.

During the "idle" period precautions must be taken to keep stock and people out of the field. Either will break any surface crust that has formed, and this will give moths an opportunity to lay some of their eggs in the field.

Since it is impossible to avoid loosening the surface of the soil when crops are being harvested during the egg-laying period, there is no practical method for protecting these fields from the moths. In this connection it should be remembered that the use of a combine after the first week of September will avoid breaking the crust during the period in which most of the eggs are being laid.

When practical, during periods of bad cutworm outbreaks, it is advisable to seed wheat only in properly prepared summerfallow. If this cannot be done some benefit can be derived from deep fall ploughing. If this be 6" deep, and the furrows are turned completely upside-down, the majority of the eggs are buried so deeply that few of the very small unfed cutworms will reach the surface in the spring. This control measure cannot, however, be recommended for use in any district in which there is much likelihood of soil drifting.

2. Bait.

For any cutworms that feed above ground, bait, *if properly applied*, probably will prove to be an effective control measure. For those that feed entirely below ground it will never be of sufficient value to warrant the expense or the labour of employing it.

Formula for Cutworm bait:

Bran	100 lbs.
White Arsenic, or Paris Green	4 lbs.
Molasses	1 gal.
Water	7-8 gals.

Method of Mixing. On page 13 is described the method for preparing grasshopper bait. The same procedure should be adopted, the only difference being that no sawdust is employed in cutworm bait.

Application when used broadcast. The following recommendations, condensed from Dr. K. M. King's pamphlet on Red-backed Cutworms, apply to all other surface feeding species:

"For success *three* conditions are essential: *uniform* spreading, application during the *evening* and favourable *temperature*. It is essential that a warm, but not too hot, evening be chosen for its application. If a thermometer in the shade registers less than 50°F. at sundown, it will be too cold for good results, and the bait should not be put out. Particularly good results can be obtained when the soil is moist, hence, whenever it is possible, spread the bait soon after rain if the temperature is suitable."

Not more than 10 pounds of the prepared bait are required to poison an acre, but the scattering must be *uniform*, since many cutworms do not crawl far in search of food.

FIG. 5—Sections of trap-furrows: A. Vertical sided furrow, for use in damp soil; B. Dusty sided furrow for use in dry soil.

Application when used in furrows. Whenever it is noticed that any kind of cutworm has the habit of crawling in large numbers across fields, and that they are all moving in approximately the same direction, it is economical in material and in labour to poison them in specially prepared furrows which are ploughed at right-angles across their line of march. In addition, much cheaper baits than bran can be employed.

Furrows for use with bait are prepared as follows. If the soil be sufficiently moist to permit ploughing a vertical-sided furrow, a plough with a coulter must be used and the earth thrown out *towards* the advancing cutworms. The furrow should be as deep as is possible, and every precau-

seen must be taken to ensure that its side is vertical and unbroken (see Fig. 5).

More frequently than otherwise such a vertical-sided furrow cannot be prepared. Either the soil is too dry or it has been unduly cultivated so that its soils crumbles. Under these conditions a dusty-sided furrow will give better results. No roughing is necessary. Plough a deep furrow, throwing the earth away from the advancing cutworms. Immediately after ploughing, before clods of earth in the furrow have dried out, drag a heavy log along it. One or two horses hitched with a logging chain to one end of a heavy gate-post, on the rear end of which the driver stands to increase its weight, has given excellent results. This breaks up all lumps of earth, leaving a fairly steep and crumbly slope (see Fig. 5), which is unpassable to cutworms, since the small particles of earth move under them. After a shower of rain, and as soon as the surface crust of earth has dried out, the log must be again drawn through the furrow.

Poisoned bran, as recommended for bran-baiting, can be scattered along the furrow at the rate of 10 pounds to 60 or 70 rods. Though the best results will be obtained when the bait is applied in the evening, the furrow can be baited at any time of the day at which cutworms are seen to be attempting to cross it. Even though there would not, at the time, be food available on broadcast bait, few of them fail to stop and eat some of it after one or two unsuccessful attempts to crawl up the side of the furrow.

A much cheaper bait can be prepared from green vegetation. In the field, look for any fairly crabby growing weeds on which the cutworms have fed. Smartweed is a favourite with many of them, and lambs-quarters or pigweed with others. Pull about 50 pounds of this vegetation, place it on a floor and sprinkle water over it till it is thoroughly moist. While turning it over with a fork, shake onto it, a little at a time, one pound of white arsenic or Paris green.

Scatter the poisoned plants 6" to 9" apart along the furrow so that ten pounds will cover about 30-40 rods. Since the vegetation remains moist longer than does bran, it is a preferable bait. The cost of materials, also, is only about .5c per rods of furrow when white arsenic is used.

Ploughing Fields after the crop has been destroyed by Cutworms.

It is never safe to reseed a field in which cutworms have destroyed the crop if the cutworms are still present in it. Some species of cutworms, particularly those which are active on the surface of the soil by day, leave a field as soon as they have eaten all of the vegetation in it. When the damage has been caused by this type of cutworm immediate reseeding is safe, though it is advisable to protect the field with furrows (see page 24). These need not be baited unless, at any time, it is seen that cutworms are attempting to cross them.

Other types of cutworms, however, remain in the devastated fields and also use a bare existence on old and dead vegetation and by feeding, to some extent, on each other. When such cutworms are present it is never safe to reseed till they are mature and have ceased to feed.

We cannot give a definite date on which reseeding is safe since, even in the same season, cutworms mature more rapidly in some fields than they do in others.

1″ long. Do not re-seed in less than three weeks.

1¼″ long. Do not re-seed in less than ten days.

1½″ long. Full-grown. Sow in about three days to one week's time.

FIG 6—Diagram to assist in ascertaining when re-seeding is safe

The diagram, given above, can be used in connection with all cutworms in order to determine when reseeding is safe.

Collect a number of cutworms from the soil of the damaged field, and pick out a few that are of the *average* size Drop them into a glass of water. Within ten minutes all will straighten out and appear to be dead. Dry them on a piece of blotting paper and compare their length with the figures on the diagram.

Unsatisfactory Control Measures that are sometimes recommended.

Coal oil, turpentine or any other material applied to the seed has no effect on cutworm activities, neither has lime, salt or sulphur applied to the soil.

Rolling will *never* kill cutworms. If the soil be damp it may slightly hamper their movements below ground. Harrowing has the opposite effect and it, too, is harmless to the cutworms.

Seeding with a press drill may be slightly beneficial in some cases, but if the drill is purchased solely for this reason it is unlikely that it will prove to be an economic investment.

Light traps, placed in the field, may capture an enormous number of moths. Since over 95% of these are males and many of the remainder are females which have already laid their eggs, they are of no practical value.

References to Literature on Cutworms in general.

Gibson, A. "Cutworms and their Control," Division of Entomology, Ottawa. Bulletin 10, 1915.

PALE WESTERN CUTWORM (Agrotis orthogonia)

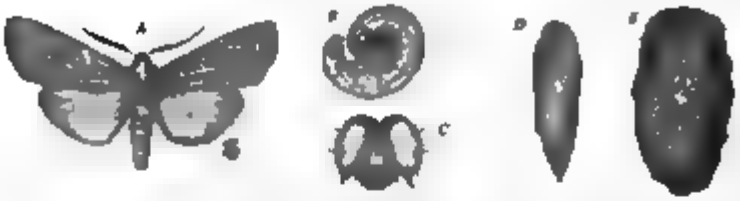

FIG. 7. Pale Western Cutworm (Agrotis orthogonia). A. Moth (Greenish grey in colour). B. Cutworm (usually slaty-grey). C. Head of Cutworm, enlarged to show smoky black, -shaped marking in front. D. Chrysalis, or Pupa. E. Pupal Cell, composed of earth. (In this figure the moth has already escaped through the hole that it has made at one end.) All, except C, natural size. (Original.)

Distribution. The normally treeless prairie of Alberta, particularly in the southern third of the province. There is little likelihood of this cutworm ever extending its range of activity into those parts of our province in which the aspen poplar is native.

Life-history and habit. The eggs are laid only in loose soil during the last three weeks in August and the first half of September. Provided it does not modify the condition of the soil surface, the presence or absence of green vegetation in the field appears to have no effect whatever upon the moths in the selection of places in which to lay their eggs.

The cutworms hatch from the eggs toward the end of April. After feeding *on the leaves* for a few days, the small cutworms enter the soil and, under favourable conditions, remain permanently below ground till they are full-grown in early June. Whenever the soil is wet, or if it is very hard, they are unable to move freely from plant to plant beneath the soil surface. Under these conditions they move, after dark, above ground, but burrow into the soil, when this is possible, as soon as they find food.

Special Control Measures

Summerfallowing. For pale western cutworms, more than for any other species, it is essential that the soil surface be allowed to become crusted throughout August and September (see page 23). During outbreaks of this cutworm, this method alone can be relied upon to hold damage in any given field to a minimum.

Delaying Spring Seeding after Cultivation. Pale Western Cutworms which have just hatched can live for a long time without food if they have never had anything to eat. Once they have fed, however *provided they are still very small* they are readily starved. This observation was made at the Dominion Entomological Laboratory at Lethbridge. It is recommended that fields in which there is danger of infestation be cultivated in the spring, soon after a green growth of weeds and volunteer grain has appeared, in such a manner that *all* of this growth will be destroyed. The field should not, then, be seeded to grain in less than ten days after this cultivation has been completed.

Use of a test strip of grass in the spring. Another method for reducing unnecessary losses in fields which are heavily infested with eggs is to ascertain, *before* the field is seeded, the approximate number of cutworms that are present. This can be done by the following method:

Before seeding any of the fields that you believe to be safe, sow two single drill widths of wheat diagonally through the field from the opposite corners. When this wheat is about 4" high examine it for cutworm damage. Remember that the smaller cutworms feed on the *blades* and that small holes eaten into these upper ends, or right through them, indicate the presence of cutworms as much as do plants that have been cut at ground level a little later in the season. If on an average of 20 plants to the square yard have been damaged, it is not safe to seed the field. It should be summerfallowed or seeded to green feed in June when the diagram (page 24) indicates that seeding is safe.

Choice of crops in fields that are believed to be infested. Pale western cutworms prefer grass to broad leaved plants, such as flax. Flax is, however, not immune from attack when there is nothing else for them to eat. It is useful for seeding in fields after the cutworms in them have matured. Corn suffers very heavily on account of the comparative scarcity of plants on which the cutworms can feed.

Treatment of fields in which infestation is patchy. Nothing practical can be done to reduce damage in a field that is infested throughout, after the crop is up.

In many fields, however, the cutworms may be confined, early in the season, to small areas scattered throughout the field. In the fall most of the field may have borne a crop, whereas these areas, which are often small knolls, had the crust broken by wind erosion or by some other cause. When this appears to be the case, examine other parts of the field for damage to the blades or for evidence of a few plants being cut. The moths lay so during a dust that the eggs are liable to hatch a little earlier in the higher and drier parts of the field than they are elsewhere, and the infestation may be general although apparently confined to these areas. If, however, the rest of the field shows little or no sign of damage, plough a deep furrow around the badly infested areas. This tends to prevent the cutworms from spreading through the field. It cannot stop them entirely, but it may reduce the spread by 50%. Under these circumstances it is, also, a useful practice to scatter some poisoned bait in the heavily infested area, and to harrow it into the soil before the furrow is ploughed around it.

Forecasting outbreaks of pale western cutworms. Much loss from these cutworms could be avoided if farmers knew when to expect outbreaks in order that they could pay especial attention to their summerfallowing methods during the previous summer. It has been shown that outbreaks are due to lack of rainfall in the previous May and June. Seamans has prepared a rough guide that can be used by all farmers in order to find out whether cutworms are liable to increase in numbers in their district. The following is a quotation from his pamphlet: "One-quarter of an inch

of rainfall is sufficient to bring the cutworms to the surface of the ground. If the sun is bright after rain they seek shade and are hidden, but if the weather remains cloudy they may become active and behave very much like ordinary surface-feeding cutworms. It has been found that when the fields are too wet to use a disc-harrow the cutworms are also likely to be on the surface, and a day with the soil in such a condition, whether raining or not, must, therefore, be considered as a 'wet' day in forecasting. When it is not actually raining, an observation in the field will be required to determine the moisture condition of the soil.

"If there are less than ten 'wet' days during the period of cutworm activity, there will be an increase in the number of cutworms the following year.

"If there are between ten and fifteen such days, there will probably be some decrease in the numbers of cutworms next year.

"If there are more than fifteen 'wet' days, little trouble may be looked for from this insect the following year."

In this connection we would point out that this refers only to the increase or the decrease in numbers of cutworms from year to year. If in any year in which there were less than ten "wet" days during the period of cutworm activity, cutworms were already sufficiently numerous to be causing appreciable damage, a serious outbreak can be anticipated in the following year. When, however, cutworms were very scarce, the same small number of "wet" days probably will not result in serious consequences. At least two successive seasons that are favourable to cutworm increase are usually necessary before a serious outbreak occurs.

References to Literature on Pale Western Cutworms.

Seamans, H. L., "The Pale Western Cutworm," Division of Entomology, Ottawa. D. of A. Pamphlet 71, 1931.

RED-BACKED CUTWORM (Euxoa ochrogaster).

Distribution. Outbreaks of this cutworm are most frequent in those parts of Alberta in which the aspen poplar is native. They may, however, occur, though less frequently in destructive numbers, anywhere in the province.

Life-history and habits. The eggs are laid in the soil during the last week in July till the end of August. From this it will be seen that the moths begin to lay their eggs *about two weeks earlier* than do those of the pale western cutworm.

We have never observed egg-laying in the field. The reason for this is that the moths apparently lay them only after dark. When they are confined in cages these moths lay all their eggs in the soil and, under these conditions, they deposit them in the loosest soil they can find. They thus appear to have somewhat similar habits to the pale western cutworm moths.

In the field we can ascertain where the majority of eggs have been laid only by observing where the young cutworms are most numerous in the

spring. Later in the season half-grown cutworms move freely from place to place. All of our observations in this connection indicate that the moths lay their eggs, wherever it is possible, *in the vicinity of* vegetation that will provide suitable food for the cutworms in the spring. The condition of the soil surface appears to be of less importance than it is in the case of the pale western cutworm. No field in which the soil was slightly crusted in the latter part of the summer has ever been found to be infested in the following spring *provided it was free from green vegetation* during the egg-laying period. On the other hand, we have no definite records of really clean summerfallow, that was being worked at the time of egg-laying, being *seriously* infested.

The favoured food of this cutworm includes a variety of broad-leaved plants. Sweet clover, alfalfa, a great variety of garden produce and weeds such as stinkweed are attractive to the moths during the egg-laying period. Where these grow in profusion it would appear that a slight crust on the soil surface fails to deter the moths from laying their eggs among the plants. In two outbreaks which occurred in separate years, we have examined the distribution of young cutworms in the early spring on the Dominion Experimental Farms at Lacombe and at Beaverlodge. The repetition of comparatively small plots which are carrying different crops and which have received a variety of cultural treatments, offers a good opportunity for observing where the majority of eggs have been laid. Sweet clover, whether it had been touched or not since midsummer, was invariably infested, whereas crops seeded into summerfallow that was *really clean* during the previous summer were practically free from these cutworms.

Elsewhere we have observed that fields which contained much stinkweed, even though they became crusted on the surface in July and August, were severely infested with red-backed cutworms in the following spring. In these fields, it should be noted, the crust *had* provided a complete protection from the pale western cutworm moths, which were also very abundant in the district.

The cutworms hatch from the eggs towards the end of April. They are mature by the middle of June. Unlike the pale western cutworm they are liable to come to the surface of the soil quite freely, even by day, and to feed on the surface almost as much as they do from below ground. As was stated earlier, they prefer broad-leaved plants to grass. When, however, large numbers of eggs have been laid in a field that was later seeded to wheat or other grain, they will feed on it, at least until they are sufficiently well developed to move elsewhere in search of something more to their liking. They are less restless and feed more extensively when they are in barley or oats than when they are in a wheat field. In the latter, by the time they are half grown, they frequently come to the surface by day and move rapidly, all travelling more or less in the same direction, over the surface of the soil.

Special Control Measures

Summerfallowing. Summerfallow should be *absolutely clean* by the middle of July, and should then be left alone till the end of August in order to take advantage of any crust that may form. If the field contains much green growth and is merely cultivated in August it will, in all probability, be rendered very attractive to the moths, since much of the vegetation is not covered and the soil surface is loosened up.

Bait. Since these cutworms feed above the ground as well as from below, poisoned bait, under favourable conditions of application, will often prove to be of value. Read carefully, on page 24, the only conditions under which bait can be successfully employed.

At any time in which the cutworms are seen to be moving towards or through a grain field over the soil surface, large numbers of them can be destroyed by the use of baited furrows ploughed across their line of march (see page 24). In this connection we have obtained the best results by employing stinkweed bait.

Choice of crops in fields that are believed to be infested. Since broad-leaved plants, such as flax or sweet clover, are preferred as food by these cutworms, it is advisable to seed grain in fields in which they are believed to be present. Wheat is the safest grain to grow since, although the small cutworms feed as freely on it as they do on barley or oats, as they grow larger they attempt to move elsewhere. Furrows for baiting should be prepared around the edges of badly infested wheat fields in order to trap and to kill any cutworms which attempt to leave them and to enter neighbouring fields.

References to Literature on Red-backed Cutworms

King, K. M., "The Red-backed Cutworm and its Control in the Prairie Provinces," D. of A. Pamphlet 69, 1927. Division of Entomology, Ottawa.

ARMY CUTWORM (*Chorizagrotis auxiliaris*).

Distribution. This cutworm has appeared in numbers, sufficient to constitute a serious menace to grain fields, only in the extreme south of Alberta. It is, however, widespread throughout the province, and during recent years has been far more numerous than formerly as far north as the Peace River District.

Life-history and habits. The eggs are laid in the soil during September. They hatch a few days after they are laid. The cutworms begin immediately to feed on any green vegetation that is present in the fields at that time of the year. They grow rapidly, and are half-grown by the time the soil freezes up. They remain inactive just beneath the soil till the following spring and, as soon as the frost is out of the ground, they come to the surface and move around in search of food. Army cutworms never feed below ground, but tend to climb up plants and to feed on the blades. When food is plentiful they remain below ground by day and come to the surface and feed only at night. When, however, food is scarce they may be very active by day and, if the sun is shining, they will all move in a *northerly* direction in search of food.

Since all feeding is done from above the surface and is confined largely to the blades, individual army cutworms do less damage than do those species which cut off the plants at the base. It is only when they are very numerous that they are liable to ruin grain crops.

Most of the cutworms are mature by the first week in June.

Special Control Measures

Summerfallow. Outbreaks of army cutworms generally develop far more rapidly than do those of other cutworms. They are unlikely to last for more than one year. Farmers, therefore, rarely have any warning with regard to when to expect them. Since the eggs are laid in freshly worked soil a crusted surface in September will protect individual fields. It must be remembered, however, that at any time during the spring, fields that were free from eggs in the fall may become infested with migrating army cutworms.

Bait. Where these cutworms are numerous they are usually first observed when the fields are being prepared for seeding early in April. They are then from ½" to 1" long. If, at that time, care is taken to *bury all green vegetation* nearly all of the cutworms will have left the field before the wheat is above ground. Precautions must, however, be taken to protect the field from later invasions, particularly along its southern side. This can be done by preparing and baiting furrows as described on page 24. Stinkweed has proved to be superior to bran for the bait, and we would recommend its use wherever it is available. Either one furrow, or two of them at a distance of about a rod apart, should be ploughed along the edge of the field. Scatter the bait at any time of the day in which the cutworms are seen to be entering the furrows in large numbers, and replenish it every three days for as long as migrations continue.

When the cutworms are found to be already present in large numbers in growing grain they can be readily controlled with bait broadcast as described on page 24.

Cause of outbreaks. The moths of the Army cutworm lay about 1,000 eggs. This is greatly in excess of the number that are laid by those of any other common cutworm. This accounts for the sudden appearance of the pest. Seamans has shown that, if the soil be dry when the eggs are laid and it remains so for a few weeks, most of the eggs perish. In a wet fall, however, nearly all of them hatch, with the result that the cutworms are very numerous in the following spring. Since it is unusual for southern Alberta to experience two wet falls in succession, outbreaks of the Army Cutworm are usually terminated as suddenly as they occur.

References to Literature on Army Cutworms

Strickland, E. H., "The Army Cutworm," Division of Entomology, Ottawa. Bull. 13, 1916.

Seamans, H. L., "The Army Cutworm," Division of Entomology, Ottawa. D. of A. Pamphlet 102, 1929.

EARLY CUTWORM (*Euxoa tristicula*).

Distribution. The open prairie areas of Alberta, particularly in the south.

Life-history and habits. Eggs are laid in the fall and they hatch a few days later. The cutworms feed on weeds and are nearly full-grown by the time the soil freezes up. As soon as the frost is out of the ground in the spring they resume activity. They mature at about the middle of May.

Although these cutworms can be found in the fields every spring they have never been very numerous in Alberta. They prefer weeds to grain and, in the small numbers in which they have occurred here, we consider them to be very beneficial since they harbour many parasites which later attack and reduce the numbers of the more injurious cutworms. In addition, they are usually through feeding before any seeded crops are above ground. Kang states, however, that they were unusually abundant in several localities in Saskatchewan in 1925, and that they caused serious injury to grain. When they are observed in large numbers he recommends delaying seeding till about the last week in May. Poisoned bait is not effective for the control of this cutworm.

GLASSY CUTWORM (*Hideodes devastator*).

Distribution. The entire province. The moths of this cutworm are very abundant every year, but the cutworms have never been found in very large numbers in grain fields.

Life-history and habits. It is not known for certain where the majority of the eggs are laid. It has been suggested that they are laid, by preference, on or in the vicinity of grass, though there is a record of their being laid at the base of a tree. In Alberta we have found these cutworms in the largest numbers in brome sod, where they do comparatively little damage.

Although they occur sparingly in clean grain fields, we have found them in destructive numbers only in fields in which an unusually large amount of grass was present. In this connection, Criddle found that, in Manitoba, they feed on grass such as wild barley grass in preference to grain.

The eggs hatch soon after they are laid, and the cutworms are nearly full-grown by the time the ground freezes up. In the spring, if no grass is available, they feed freely on grain. They rarely come above the surface of the soil, but pull entire plants into the ground and there feed on them at their leisure. These cutworms mature before the end of May.

Special Control Measures.

Since the greatest damage from these cutworms appears always to be associated with the presence of grass during the egg-laying period, care should be taken to cover and completely when it is being broken. The same precaution should be taken when cultivating summerfallow in which much grass is present.

Bait is useless for these cutworms, since they come to the surface even less than do pale western cutworms.

References to Literature on Glassy Cutworms.

Gibson, A., "Cutworms and their control," Division of Entomology, Ottawa. Bulletin 10, 1915.

WIREWORMS.

There are a large number of different species of wireworms in Alberta. Over 80 different kinds of click-beetles, into which wireworms develop, have been captured in our province. Nothing whatever is known of the habits of most of these as wireworms. Of those that are known, several are certainly harmless to grain since they live only in decaying wood. About ten different kinds of wireworms have been found in grain fields. Three or four only ever occur in sufficient numbers to cause appreciable damage, and of these one only is a widespread pest of grain crops in Alberta. This is the Northern Grain Wireworm.

A second species, which has no common name and which is very much smaller, is often associated with it in fields in which there is much sod, while a third, which is also very small, is sometimes very destructive in the extreme south of the province.

NORTHERN GRAIN WIREWORM (Ludius aeripennis var destructor).

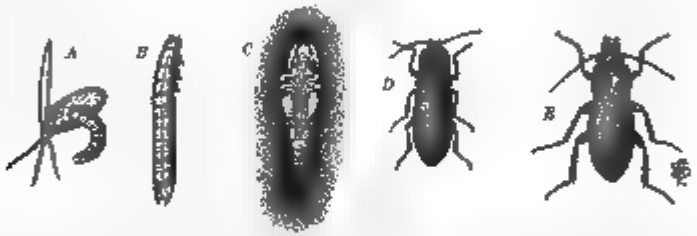

FIG. 8—Northern Grain Wireworms: A Half-grown wireworm attacking grain, B. Full-grown wireworm. (Note the flattened plate with two double claws at the end of the body.) C Pupa in cavity in the soil; D Adult Click-beetle of Wireworm. Do not confuse with E., a fast-running ground-beetle, which feeds on very young wireworms. Ground-beetles vary much in shape, but they never have the two backwardly pointing spines, one on each side, near the middle of the body. All figures natural size. (Original.)

Since we have little information regarding the two smaller species of wireworms, we will confine our attention particularly to this widespread grain pest.

Distribution. Widespread throughout the province, but not often encountered in destructive numbers anywhere except in the central part of Alberta and in the Peace River District. Although it is quite common throughout the southern part of the province, it is less abundant there than it is farther north, and is usually associated with other species of wireworms and with False wireworms, with which it is liable to be confused. In those areas of Northern Alberta that were originally fairly densely covered with trees or bushes it rarely occurs in sufficient numbers to cause appreciable damage.

Length of life and variation in annual damage. In the case of most insects the life-cycle is completed in a single year. It is important to bear in mind that this is not the case with wireworms. We do not, as yet, know how long a wireworm can remain, as such, in a grain field.

In 1930, we hatched a large number from eggs. They were placed in cages on a grain field at Edmonton, where they lived under conditions which differ little from those to which they would be exposed were they living a normal free life elsewhere in the field. There is a heavy annual mortality due chiefly, to their cannibalistic habits during the summer months. None die during the winter and all specimens which were given cages to themselves finally matured into beetles. The first beetles to mature did so in 1931. Since these would have laid their eggs in 1934, the shortest life-cycle obtained on these cages was four years.

Each year thereafter more of them matured until 1938, when the last five turned into beetles, which would have laid their eggs in 1939. From this, we concluded that the life-cycle varied, in the field, from four to nine years.

A second, and much larger, series of cages was, however started in 1932. As before, the shortest life-cycle recorded was four years, but when the cages were examined during the winter of 1941-42 it was found that two were still wireworms! Whether these two survivors will decide to mature during the late summer of 1942 we are unable to say but it is now proved that wireworms *can* live at least eleven years in the field, even though the majority of them mature in about three years or seventh year.

The importance of this will be recognized when efforts are made to reduce these numbers by the methods described on page 34 for the destruction of eggs and pupae. Although the control measures may have been quite effective in that respect they cannot be expected to give immediate relief. They will, in fact, yield no results in the following year. Only after three consecutive explorations over a number of years can any appreciable benefit be anticipated. Unfortunately, we know of no practical method for obtaining such immediate relief, by the destruction of the wireworms themselves, in grain fields.

It will be realized also that the *total* number of wireworms in any field will not often vary very much from year to year. The actual damage which they may do in the same field, however, is subject to great annual fluctuations. The same population of wireworms—even though nearly all of them are the same individuals—may do little damage one year, scarcely ruin the crop in the next and cause no appreciable loss in the year following. This is due to the fact that wireworms can live for at least two years without feeding on growing vegetation and they will feed extensively only in those years in which they find that the temperature and moisture conditions in the soil immediately surrounding newly-seeded grain are to their liking.

Life-history. The beetles lay about 300 eggs in the soil, during May and June. Minute wireworms hatch from these in about one month's time. They grow slowly during the next five (possibly 3 to 10) years.

However many years old they may be, they always mature at about the middle of July. Then at a depth of less than 4" from the soil surface, they make small cavities in the soil, and in these transform to helpless, very soft, white pupae. Within three weeks these have again transformed into beetles, which remain inactive in the soil till the following spring.

Habits of Wireworms in all stages of Development.

Beetles. These are known as "click-beetles" or "snappers," because if they are placed on their backs on a smooth surface they soon jump into the air with an audible "click." No beetles other than those of wireworms do this.

Although they normally remain inactive in the soil throughout the winter, they are not harmed if they are disturbed by fall ploughing.

In the spring, as soon as the soil warms up in March or April, they struggle to the surface and, on fairly warm days, they wander over the fields. The egg-laying females *never fly*. They probably rarely move very far from the place where they lived as wireworms before laying their eggs, since in their wandering they often retrace their steps.

Egg-laying. Late in May and throughout June the females make frequent trips into the soil for the purpose of egg-laying. Depending upon the temperature, moisture and firmness of the soil at this time, they deposit eggs at any depth from just below the surface to 5 or 6 inches deep. One beetle in captivity made eleven such trips in a month and laid a total of 252 eggs.

Eggs which are laid very near the surface of the soil rarely hatch since, at some time before they normally would do so, they are dried out or are killed by heat. It would appear that, in average seasons, eggs laid at less than 2" from the surface are in danger of destruction in this manner. On the other hand, eggs that we have placed 5 or 6 inches deep in the soil have never failed to hatch.

Food requirements of very small wireworms. As soon as the very small wireworms hatch they burrow in the soil in search of food. If within about a month they fail to find any that is suitable, nearly all of them will have died of starvation. This is a long time for them to be able to live without food, but the fact remains that, at this time, they *can* be starved. After passing their first winter they can live for at least two years without food other than humus, which is universally present in soil. From this the impossibility of starving half-grown wireworms by clean summerfallowing will be appreciated.

The question naturally arises as to what constitutes a satisfactory source of food for newly hatched wireworms. Germinating grain and the roots of grain and of many grasses certainly supply their needs. It is very doubtful whether the seeds or the roots of many weeds will do so. In the laboratory they fail to survive when offered such plants as shepherd's purse, ramblerweed, lamb-quarters and many other weeds on which older wireworms feed freely. It should be noted that they will eat these plants

but survive for no longer than do others which are starved. A few have survived on flax and on Russian rapeseed, but the presence of living grain or grasses appears to be essential if many of them are to do so.

Feeding habits of older wireworms. When the ground freezes up all wireworms become entirely inactive till the following spring. Their habits are the same from year to year. As soon as the ground warms up they resume activity. When a field, in which they are present, has been seeded with grain, they attack the seeds and eat out the starchy food material that they contain. The plant is thus starved, and it fails to come above ground. Very small wireworms frequently eat only the embryo, particularly if the soil is inclined to be dry. The result is the same—the plant does not appear above ground.

Having destroyed one seed the wireworm moves, usually along the drill row, and destroys the one next to it. In this manner a single, fairly large wireworm may prevent a dozen or more adjacent plants from appearing above ground. A little later in the season, when undamaged plants are above ground, the wireworms turn their attention to the stems and bore through them well below the ground level. Plants attacked in this manner do not fall over, as do those that are killed by cutworms. The leaves wither and become tightly rolled up. This is very characteristic of wireworm damage.

Still later, when the plants are beginning to stool out and the stems are becoming thicker and tougher, the wireworms no longer cut them off completely. They bore a small hole through to the central shoot and feed on it only. As a result the central leaves of the plant turn yellow and die, though the older ones may show no sign of damage above ground.

At about this time, which is early in June, the wireworms tend to leave off feeding. By the time the plants are fully stooled out little further damage is seen.

It is important that we understand why damage is reduced or entirely ceases in June, even though the wireworms are still present in the field. Wireworms never come above ground. They feed only in *fairly cool moist earth*. Early in the spring they are able to come, and to feed, nearly to the surface of the soil. As this dries out and heats up later in the season they burrow more deeply to cooler, moister earth. By the middle of June, in normal seasons, they are below the level of the seed, and such feeding as they do is confined to the roots which, as a rule, are not very seriously injured.

Pupation. By the middle of July all full-grown wireworms work their way upwards in the soil and come to rest at about two to four inches from the surface, provided the soil is not too hot and dusty for them to make a small cavity in the ground in which to pupate. Here they soon turn into delicate white pupae which are very easily crushed if the soil that surrounds them is disturbed. When, early in August, these have turned into hard-shelled beetles they are very difficult to destroy.

Control of Wireworms.

Methods for reducing wireworm damage fall into two main categories.

1. Reduction in the number of wireworms that are present.
2. Reducing damage to the crops even though the number of wireworms that are present cannot be reduced.

It is obvious that the first is the more desirable. Effective methods for killing wireworms have been developed in market-garden districts where land is frequently valued at $1,000 an acre. This valuation warrants excessive expenditures in maintaining productiveness. Such methods, which cost in the neighbourhood of one to three hundred dollars an acre, are out of the question for grain raising.

No entirely satisfactory method for destroying wireworms in grain fields, or for reducing the feeding activities of those that are present, has been discovered. There are, however, a number of different methods, each of which affords some measure of relief. By employing *all* of them damage may be appreciably reduced.

Cultural methods for reducing the number of wireworms. In districts which are infested with wireworms it is usually in the fields that have been for the longest time under cultivation that damage is most severe. There are, of course, exceptions to this rule. Wireworms are native to Alberta. In virgin soil they appear to thrive only where the soil is unusually loose and deep. Where such areas occur they are referred to locally as "loose-top." They usually are comparatively small, some two to three rods in diameter.

When a field that contains areas of "loose-top" is first broken and seeded to wheat, the crop in these areas may be completely destroyed by the large number of wireworms in them, while there is little damage throughout the rest of the field. After a few years of cultivation, however, the wireworms become spread throughout the field. This spread is usually accompanied by a serious increase in their numbers.

Experiments indicate that one reason for the abundance of wireworms in "loose-top" is that the natural condition of the soil in such areas is ideally suited to the requirements of egg-laying beetles. These beetles are unable to burrow into firm earth. In hard virgin sod they fail to penetrate into the soil to a sufficient depth in order to safeguard their eggs from destruction by heat and desiccation. In "loose-top" they can, however, burrow readily to five or six inches, at which depth all of the eggs they lay are practically certain to hatch.

The usual practice employed for summerfallowing is to plough deeply in May or June. This is just before, or at, the time when the beetles are laying their eggs. By this method the soil texture of the entire field is modified into "loose-top", and the beetles can burrow readily to plough depth. It is essential that the sub-surface soil be kept as firm as is possible during the egg-laying period, in order to induce most of the beetles to lay their eggs in the superficial layers.

It should be remembered, also, that during the *last half of July* all mature wireworms turn into helpless pupae. These are located as near to the surface as it is possible for these wireworms to make a small cavity in the firm earth. Pupae are readily destroyed if the soil that surrounds them be disturbed. At no other stage in their development can wireworms be destroyed *mechanically* with a cultural implement. It is only at this time of the year, therefore, that deep ploughing is of value in reducing their numbers by mechanical destruction.

We recommend, therefore, the following modification in summerfallow methods in fields that are badly infested with wireworms.

1. Early in the spring, cultivate to a depth of not more than 2½", the shallower the better. This will encourage the germination of weed seeds that are near the surface.

2. Repeat shallow cultivation, as often as is necessary to *destroy all weed growth*, till the middle of July. This loosens the surface and packs the ground to some extent below the depth of operation, thus encouraging shallow composition. Early in the season wireworms are near the surface and many of them are exposed to destruction by birds. Each operation, also, brings many of the eggs which are laid in the loose earth right to the surface, where they are certain to perish, and it also tends to aerate all of the worked soil. Finally, it should result in the germination and destruction of all volunteer grain on which any small wireworms that manage to hatch thrive better than on anything else.

3. During the last half of July, plough or cultivate about one to two inches *more deeply* than formerly. If the earlier work has been properly done, all mature wireworms will have come to the surface layers of the firm soil for the purpose of pupation. This somewhat deeper cultivation will destroy nearly all of the pupae. Do not, however, set the implement to work any more deeply than is necessary to break about an inch into the firm soil. The more the subsoil is loosened the more easy it is for any beetles which may survive to burrow deeply in the following spring for egg-laying.

It is *essential* that this somewhat deeper cultivation be not delayed till August. The beetles are then formed, and they will be in no way damaged by the plough or cultivator.

4. This method of summerfallowing should be followed consistently in all badly infested fields. Its employment in other fields, in which wireworms are not numerous, will reduce the danger of serious infestation.

Deep ploughing or cultivation should, at all times, be avoided. If, for any reason, it is essential, it should be deferred till after the middle of July.

This method aims at destroying as many eggs as is possible, at starving most of the newly hatched wireworms, at exposing as many half-grown wireworms as is possible, and at destroying pupae which would have developed into egg-laying beetles in the following year.

It must, however, be borne in mind that summerfallowing by this method cannot have a very marked effect on the number of destructive

wireworms that will be present in the following year. The greatest damage is done by wireworms which are from three to five years old, and their numbers will not have been greatly affected. The best that can be claimed for it is that it tends to *reduce* the steady increase in wireworm numbers rather than to *increase* it.

Cultural methods for reducing wireworm feeding. As has already been pointed out, wireworms cannot be starved except when they first hatch. Furthermore, they eat very little when conditions in the field are not favourable for feeding. Maximum feeding takes place in soil that is quite damp and fairly cool. Firm soil retards their movement in search of food.

We have experimented with the use of press drills, packers and seeding at different depths and dates in order to ascertain their effect on wireworm damage. This work was conducted at the Dominion Experimental Station at Beaverlodge through the courtesy of the Superintendent, Mr. W. D. Albright, and with the aid of a grant made for that purpose by the Dominion Research Council.

Although carefully checked experiments were conducted during one season only and the results were not very conclusive, they tended to confirm those which have been obtained by other investigators. They are as follows:

1. Seed only in a well-prepared seed-bed in which moisture is close to the surface.

2. Seed as shallowly as is possible with the assurance that the seed is well down to moisture.

3. *Combined with shallow seeding,* use a press-drill, or press-attachment, or else pack at right angles to the drill-rows immediately after seeding. In our experiments we found *more* damage when grain was seeded 4" to 6" deep with a press drill, or when it was packed, than there was when it was simply seeded at similar depths with a disk drill. It was only when it was seeded 2" deep that pressing or packing produced any benefit. We cannot state whether this will always be the case, but hesitate to recommend the use of a press-drill or a packer except in the case of shallow seeding.

4. Grain seeded as late as the middle of June is not likely to be damaged seriously. Wireworm feeding is nearly over for the year by this time. It is useful to bear this in mind in connection with reseeding, even though it is then too late to reseed with wheat.

It is impossible to state, for all seasons, whether early or late spring seeding is advantageous. When the soil is really cold wireworms hardly feed at all, though, at the same temperature, the grain is softening prior to germination. This gives the grain a start, so that it can grow rapidly when the soil warms up. If, however, the soil remains somewhat cool, and subsequent growth is slow, the wireworms have longer to feed on the germinated grain and small plants. Generally speaking, early seeding is preferable, but *rapid growth* is a matter of great importance in reducing damage.

Use of Fertilizers Everything that is possible should be done to encourage rapid germination and *development* of the plants. In many districts in Alberta there is a serious shortage of phosphates in the soil. Phosphates encourage early development of roots when they are applied at the time of seeding. This makes the plants more resistant to wireworm damage. Where phosphate shortage is indicated, it has been found to have a marked effect on wireworm damage. At Beaverlodge, Mr. Albright finds that applications of phosphates do not have as stimulating an effect on wheat as they do in some other districts, and their application did not appreciably reduce wireworm damage.

Treatment of the seed or of the soil with chemicals to reduce wireworm damage Claims are made frequently to the effect that grain treated with coal-oil, turpentine, lime, tar, and a variety of other materials is less subject to wireworm damage than is seed not so treated. When these materials have been tested under experimental conditions none of them has been found to be of the slightest value for this purpose. Several retard germination and do more harm than good. In all fairness to those who make these claims it should be remembered that, on account of variations in climatic conditions, the amount of wireworm damage varies greatly from year to year. Fields which are selected for these experiments are, almost invariably, ones that have suffered abnormally heavy damage during the previous year. A perfectly normal decrease in damage during the following year is naturally attributed to the treatment that has been employed, even though it has nothing whatever to do with it. The reason for the annual variation in damage is discussed on page 35.

A few materials can be applied to the soil in order to kill wireworms that are present. Since, however, the cheapest of such materials cost in the neighbourhood of a hundred dollars an acre in materials and labour, they are of no significance to the grain producer.

Treating grain for smut etc. Whenever grain is treated with formalin, germination will always be retarded. Thus, inevitably, increases wireworm damage. This unnecessary damage can be avoided by treating grain *only with materials other than formalin*.

References to Literature on Wireworms

Strickland, E. H. "Wireworms of Alberta," University of Alberta, 1927.

FALSE WIREWORMS (Eleodes hispilabris).

FIG. 9—False Wireworm.—A. Full-grown False Wireworm. (Note that hinder end of the body is pointed.) B. Adult beetle standing on its head as it does when it is disturbed. These beetles must not be confused with the rapidly running Fiery Hunters (see Fig. 6). Natural size. (Original.)

Distribution. These are rarely seen anywhere except on the open prairie. Most abundant in the south and east, where rainfall is light.

Life-history and Habits.

Beetles. Very clumsy black beetles, about 1" long. They walk slowly and have the ridiculous habit of standing perfectly still on their heads when they are mildly alarmed. In addition to this, they frequently fall into gopher holes, and take so long to drag themselves out that many people think they must have some relationship with gophers. Young beetles first appear above ground in the late summer. They feed on the foliage of a variety of weeds till the weather turns cold, when they wander extensively over roads, etc., in search of suitable places in which to pass the winter. The most favourable location for this purpose is under dense masses of dead weeds. Here they remain till the spring, when they resume activity and feed on young Russian thistle and other weeds. At about the middle of June they lay eggs just below the surface of the soil, but continue to live till the following fall, or even longer.

False wireworms. The larvae closely resemble wireworms. They are, however, cylindrical and the end of the body is rather sharply pointed. The best character for distinguishing them is, however, their extreme activity. Place one on the open hand. It will immediately whip its body around in all directions till it succeeds in jumping to the ground, into which it will immediately burrow. No wireworm does this.

Young false wireworms hatch from eggs in July and are half-grown by winter. In the spring they feed in a somewhat similar manner to wireworms, though they do far less damage. They are mature by August when they pupate in the soil and soon turn into beetles, which come to the surface immediately and feed on weeds till low temperatures force them to seek winter quarters.

Economic Importance.

False wireworms do comparatively little damage. They attack grain less extensively than do true wireworms, and they appear to prefer nibbling at the roots to feeding on the stem. There are several different species of false wireworms, and Criddle has observed, in Manitoba, that some of them come above ground at night and feed on the blades and stems of grass plants. We have not noticed this in Alberta, though doubtless the habits are the same here as elsewhere. Such damage as they do renders it advisable to keep down their numbers as far as is possible.

Control Measures.

The most practical control measure for false wireworms is that of keeping the soil surface as free from dead vegetation as is possible during the winter. Abnormal abundance of false wireworms in any field can nearly always be traced to large quantities of Russian thistle or mustard, particularly two winters previous to their greatest abundance. In no stage of development can false wireworms be starved. They can be bred from egg to adult on damp soil which contains no living vegetation. It is

possible that this accounts for their causing much less damage than do wireworms. They never *require* living plants for food.

WHEATSTEM SAWFLY (Cephus cinctus).

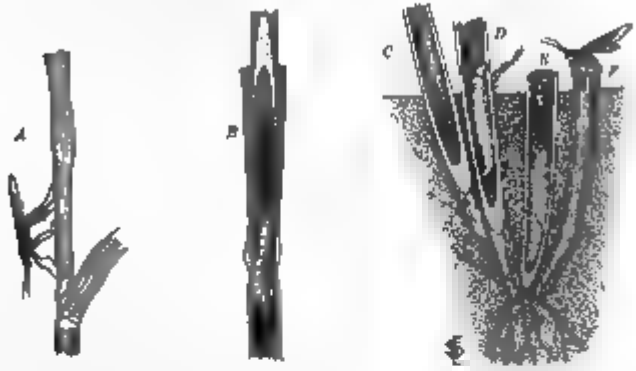

FIG. 10—Wheat-stem Sawfly: A Sawfly laying an egg in a young wheat plant; B. Grub inside straw. It has just eaten through a solid node. Note the "sawdust" that partly fills the straw. C An uninfested straw. D Grub cutting infested straw at harvest time. E Grub which has plugged the straw stub with "sawdust" and has made a cocoon within which to pass the winter. E Sawfly escaping from stub in the spring, after pushing out the plug of "sawdust." All figures natural size. (Original.)

Distribution. The present distribution of this pest is in the eastern half of Alberta about as far north as Camrose. It is improbable that it will spread much farther northward, but it is likely that it will gradually extend its territory in the direction of the foothills to the west. In this connection it should be noted that the sawfly as a grass-inhabiting insect is found all over Alberta, including the Peace River District. Elsewhere than in the south and east of the province, however, it attacks grasses only, and there is little likelihood of it becoming a pest of wheat.

Life-history and Habits.

Sawflies. The adult sawfly is a small black and yellow wasp-like insect with dark wings. It is about ½" long. Sawflies first appear on the wing late in May, and they continue to fly till the middle of July. They are very inactive, and spend most of their time resting on stems of grain or grass. When they do fly, they remain near the ground and travel only a short distance before re-settling. In so far as is known, they require no food other than water.

Egg-laying. The majority of eggs are laid in June, though in some years many are still being laid as late as in the middle of July.

The sawfly settles head-downward on the young wheat plants and, with a pair of saws at the end of her body, she cuts a slit through the leaf-sheath into the flowering stem somewhere below the developing head. Through

thus slit she forces a small white egg. Any number of sawflies will lay their eggs in the same stem. This is an important thing to remember in connection with control. One of the grubs which hatches from these eggs will eventually kill all the others that are present. From this it is evident that the more we can crowd the sawflies at egg-laying time, the greater will be the mortality among the grubs.

Grubs. The small grubs which hatch from the eggs burrow downwards within the hollow straw and eat their way through the solid nodes in so doing. The straw, through which they have passed, is partly filled with a sawdust-like material. The head, meanwhile, develops normally. Though there may be a slight reduction in the yield of attacked stems this is not very serious. By the time the head begins to ripen, all of the grubs are below ground inside the straw. They now turn round, so that their heads are uppermost, and cut off the straw at a point that is usually about 1" above the ground.

After plugging the open end of the stub with "sawdust," the grub spins a delicate silken cocoon in which it remains more or less inactive until the following spring, when it pupates and later escapes as a sawfly by pushing out the plug.

Plants that are attacked.

Originally sawflies laid their eggs only in native grasses. Now, however, they lay them as readily in all grain crops. The grubs can mature successfully only in *spring wheat* in *spring rye* and in a variety of native and cultivated *grasses*. Although eggs are laid freely in oats the grubs that hatch from them die almost immediately and do no damage to the crop. They live somewhat longer in barley, but very rarely mature.

Effect of Climate on Sawfly abundance.

Generally speaking, moderately dry seasons are favourable to sawfly abundance. Not only do they do more damage in such seasons, but they will be present in increased numbers to attack wheat in the following year. Excessive moisture, or extreme drought, in June and July reduces their numbers; but once they have appeared in a district they will always be present in sufficient numbers to cause severe losses when climatic conditions are favourable to them.

Control Measures.

Cultural Methods for destroying Sawflies.

Deep fall ploughing. Since every sawfly that has bred in wheat passes the winter in the stubble, it has been considered that if, in the fall, the infested stubble be ploughed into the ground with a mouldboard plough, few of the sawflies will be able to escape in the spring. Our own experiments have proved that fall ploughing destroys very few sawflies. It, however, greatly retards their development in the spring. This delays egg-laying, and for this reason it is somewhat beneficial. Spring ploughing has very little effect on the sawflies.

Fall Cultivation. In those areas in which snowfall is light, *shallow* fall cultivation gives better results than does deep ploughing. The object of

much cultivation is to drag as many of the infested stubs to the surface as is possible and to leave them exposed throughout the winter. Only in those stubs that are entirely exposed will the contained grubs perish. The cultivator should, therefore, be set to work no more deeply than is necessary to drag them out.

It should be realized that this type of cultivation will produce a "trash mulch" which should prove to be of value also in reducing soil drifting.

Stubble burning will not destroy the grubs. They are too far below ground to be affected by the heat even when a stubble burner is employed.

Rotation by Crops and Trap Cropping

Rotation.—*Never seed wheat in a field in which sawflies damaged the crop in the previous year.* To do so in a field that has simply been spring ploughed will increase the damage in so far as it is humanly possible so to do. It is hardly less safe after fair cultivation or ploughing. Grow wheat only after clean summerfallow or after some unwanted crop such as oats, barley or flax that was *free from volunteer wheat*.

Trap crops. All clean wheat fields should be protected from invasion by egg laying sawflies with a trap crop seeded around their edge.

In May and June, when recently emerged sawflies are seeking suitable stems for egg laying, they fly near the ground till they reach a growth of grass or grass that is about 6 or more in height. Having found this, they move very little again but remain in it till they have laid their eggs. If they enter the edge of a well advanced wheat field they usually lay nearly all their eggs within the first two rods from the edge. If however, the field be backward they may scatter throughout it before the plants are of a sufficient height to attract them for egg laying. Thus the whole field is liable to be affected, with a concentration on the earliest developing knolls. Farmers cannot avoid trouble, with any certainty by seeding either earlier or later than their neighbours.

A trap-crop grown around the edges of the field is the most common method for reducing infestation. This consists of a more vigorous growth of a suitable grass or grass than that in the field to be protected.

Brome Grass seeded along the headlands and fence-rows, is the most effective permanent trap-crop that can be grown. It is very attractive to the sawflies for egg laying, and it makes the necessary vigorous growth in the spring. When sawflies are abundant they lay many eggs in almost every stem of this grass. In the protected field each of these eggs might have been laid in a separate stem. At the most, one grub only can survive in each stem, but as brome thus sought survivor has a poor chance to mature. Many die a natural death in this grass, as they do in barley. Many more are killed by other insects, their parasites. The heavily infested trap-crop of brome will not, therefore, breed many sawflies, but it probably will produce a large number of parasites. Unfortunately, those parasites which attack sawfly grubs in brome are far less successful in attacking those that inhabit wheat. Mr. Seamans finds, however, that if the grass be cut for hay at about the middle of July, parasitism will increase in nearby wheat.

This is due to the fact that the parasites have two generations a year, and that the second generation are seeking sawfly grubs in which to lay their eggs at this time.

The greatest advantage from seeding brome along the fence-rows is that, once it is established, and if rotation of wheat with any other crop or with summerfallow be practised, the wheat-stem sawfly will be permanently held to comparatively harmless numbers in all fields so protected. In addition, it must be remembered that the brome will yield valuable fodder on this normally useless land, and that it crowds out many weeds which otherwise would grow later.

Oats or Wheat can be employed for *temporary* trap-crops. Each has its advantages under different conditions. In either case the trap-crop consists of a single drill-width of grain seeded *as early as possible* around the edges of the field to be protected. It is essential that it be well in advance of the wheat in the field when the sawflies are flying at the end of May and in June, and it will prove more effective if a drill width of bare ground can be left between it and the crop to be protected.

Oats have the advantage that all sawfly grubs from eggs laid in them perish. As a result there is no necessity to cut them before they are ripe.

Wheat has the advantage that in certain seasons the straw lengthens more rapidly in early spring than do those of oats. When the season is such that early development is slow, or trap-crop seeding is of necessity much delayed, an oat trap may not be sufficiently advanced to prevent the sawflies from flying through it before the end of May. Another advantage is that there is no danger of oats being mixed with the wheat crop at harvest time. This can, however, be eliminated by seeding an oat trap around infested stubble instead of around the neighbouring wheat field to be protected. The main disadvantage of wheat as a trap crop is that it must be cut for green-feed by the middle of July in order to destroy the sawflies that it harbours. This reason alone renders oats in most seasons preferable to wheat.

Control Measures adapted to Strip Farming.

In fields in which it has been found necessary to adopt "strip farming" methods for reducing the danger of soil drifting, the problem of sawfly control is more difficult than it is elsewhere.

We would stress the value of protecting each such field with a brome grass trap-crop seeded around it.

If, in any year, sawfly damage is observed at harvest time, all of the stubble strips should be shallowly cultivated as soon as is possible. This should destroy at least ⅔ of the sawflies which would, otherwise, have hibernated here. It will, also, produce a trash mulch to reduce the danger of soil drift. In the following spring, seed as early as is possible in order to keep the majority of the egg-laying sawflies in the outer rows of the wheat.

Should the sawflies, however, become a serious pest in such a field the most satisfactory treatment would be to replace the wheat in it with oats,

barley or fall rye, for one year, during which every effort should be made to assure that the entire field is free from a volunteer growth of wheat in which the sawflies could continue to breed.

This should, largely, free the field from sawflies, and the brome trap-crop will delay a serious re-infestation.

Cutting Wheat on the "Green Side".

Sawfly grubs sever the straw only when the latter is beginning to dry out at the base. At this time, whatever the rate of maturity, the grain is beginning to ripen. It is possible to harvest a *uniformly maturing* field just ahead of the appearance of sawfly damage without causing serious shrinkage. In this manner most of the damage can be avoided. Experience alone will inform the farmer of the first day on which he can begin to cut. He will, however, have only about four or five days during which he can harvest in safety before the grubs begin to cut down infested straws. It is necessary, therefore, to concentrate during this period on the worst infested fields.

At about two weeks before harvest, gather at least 500 straws selected from different parts of the field. Split each one open. Every straw that contains a sawfly grub will be partly filled with a sawdust-like material. If 70% of the straws collected in a certain part of a field are infested, approximately 70% of the crop will be lying on the ground if it is not harvested till it is dead ripe. In another part of the field, or in another field, 2% only of the straws may contain this dust. Obviously, there is no urgent necessity to cut this area early, but every effort should be made to harvest as much as is possible of the first before damage shows up.

Implement manufacturers are now producing teeth to be fitted to combines which will gather many of the fallen straws. Their use greatly reduces losses.

References to Literature on Wheatstem Sawfly

Criddle, N., "The Western Wheatstem Sawfly," Entomological Branch, Ottawa. Pamphlet 6, 1924.

Strickland, E. H., Methods of Reducing Wheatstem Sawfly Damage," Department of Agriculture, Edmonton, 1930.

Forstad, C. W. "Control of Wheatstem Sawfly in the Prairie Provinces," Special Pamphlet No. 59, Dominion of Entomology, Ottawa, 1941.

WHEAT STEM MAGGOT (*Meromyza americana*).

Distribution. Uncommon in Alberta, but liable to be scatteringly present anywhere in the province.

Life-history and habits. The maggots are the larvae of a very small green and black fly which lays its eggs on the blades in June. The young maggots, on hatching, work their way inside the leaf-sheath to the top node. Here they feed on the flowering stem and entirely sever it from the plant. By the end of July the head dies and turns white.

Control. There is no practical control measure for wheat-stem maggots in the small numbers in which they occur in Alberta.

Trap crops and poisoned bait for the flies have been employed elsewhere where the insect is more abundant.

WHEAT SHOOT MINERS (Hylemyia cerealis, etc.)

Distribution. As yet these insects have been recorded as attacking wheat severely only in the southern half of the province. Light infestations are, however, widespread.

Life-history and habits. The flies, which much resemble house-flies, are active shortly after the grain is above ground in the spring. They lay their eggs on the young plants. Their maggots are very similar to root-maggots of cabbages. They burrow into the plant and feed chiefly on the central shoot. When the plants are very young, they may be killed outright, but if more than about three blades have been formed it is probable that only the central shoot will wilt, while the older blades continue to grow, though they may assume a bluish tint.

In a badly attacked field it may appear, during the latter part of May, that the crop is entirely ruined. At about the time that the owner decides to plough it in, it is probable that a marked improvement will be noticed. This is due to the fact that the maggots have matured and have left the plants in order to pupate in the soil.

Control. There are few records of wheat fields in Alberta being badly infested with this insect. When its presence is suspected a few plants should be pulled up and torn open in order to expose any maggots which may be present near their base. If these are "wedge" shaped, i.e., much narrower at the front end than at the other, they are one of the Wheat Shoot Maggots. Having thus determined the cause of the trouble, the farmer should be in no hurry to take any action. Provided there is sufficient rainfall, most of the attacked plants will recover, and their development will be found to have been retarded very little despite their unhealthy appearance earlier in the season.

Deep fall or spring ploughing reduces the number of flies which will emerge during the spring.

HESSIAN FLY (Phytophaga destructor).

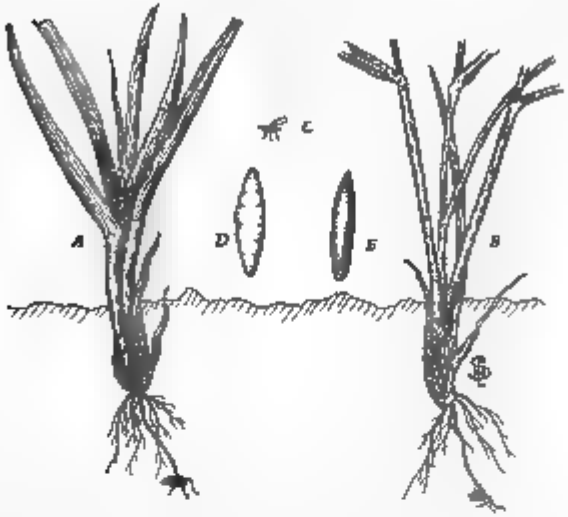

FIG. 11.—Hessian Fly.—A. Wheat seedling attacked by Fly, showing two "Flax-seeds" near base. B. Healthy wheat seedling, about 6" high, in same stage of development as A. C. Hessian Fly, about life-sized. D. Full-grown maggot (much enlarged). E. "Flax-seed" (much enlarged). (Original.)

Distribution.—In 1916 this European wheat pest, which many years earlier had been accidentally imported into the Eastern States, spread from the south into the fall-wheat growing area in the extreme S.W. corner of Alberta. At about this time the farmers in that part of the province gave up growing fall wheat and the Hessian Fly disappeared.

In 1939, it suddenly reappeared over a large area in central Alberta and, by 1940, it was known to extend from Lloydminster and Wainwright, on the east, to as far west as Tofield and Camrose. During the latter summer it, apparently, died out and it is to be hoped that it will not reappear in our province.

Since, however, during these two years many fields suffered from a 15% to a 25% infestation, it is obvious that, under certain climatic conditions, it can live and over-winter here. For this reason, everyone should be acquainted with the type of damage it causes and the control measures which are recommended for it.

Life-history and habits.—There are two generations of the Hessian Fly each year. The maggots of both attack wheat freely in Alberta. It is stated that, in Manitoba, they also attack barley and rye. Oats are practically immune, but several species of grass may be infested.

The winter is passed in the pupal ("Flax-seed") stage. In so far as we know, the majority of them are to be found in the straw-piles of the

current year's crop. Others, probably, are present in or on the ground in which the infested wheat was grown.

During May the mature grain-like flies escape from the pupae and lay their eggs on the blades of wheat seedlings. From these eggs emerge very small, oval, maggots which have a "pearly" lustre. These work their way below ground between the blades, on which the eggs were laid, to the "bulb" of the seedling. Here they feed on the inner central shoot which wilts and dies. The outer leaves remain stunted, become somewhat broader than usual and assume a bluish cast. In all cases which we were able to observe, the plants were able to produce stems, which soon replaced the first shoot, though thus failed to make any further growth. The damage caused by this first generation of the flies did not, therefore, appear to be very severe.

By about the middle of June, the grubs are mature and they turn into a pupa which is small, reddish and hard. They are of about the same colour and size as a flax-seed. Although the resemblance is not very great, these pupae are universally termed "flax-seeds". All of the flax-seeds which we obtained during May and June in 1940 produced a second generation of flies during July. It is stated that, in Manitoba, many of them fail to do so until the following May and that they, therefore, remain in the infested stubble throughout the following winter.

The flies which emerge in July again lay their eggs on the blades of the heading wheat. The blades usually selected are those arising from the second or third node above ground level. The second generation grubs from these eggs travel down within the leaf-sheath to the node. Here they feed on the stem which becomes so weakened at this point that it falls over before the grain is ripe. By harvest-time practically every infested stem has fallen over and is lodged against neighbouring plants. An examination of the point at which the stem falls over will, almost invariably, reveal a "flax-seed" within the leaf-sheath. Here it will remain until the grain is threshed.

Damage. In the fall of 1939, when several fields were observed in which about 15% of the stems were infested, the grain from a similar number of affected and of unaffected heads was threshed out separately. That from the former was distinctly "off-colour" and had a greenish tinge which did not disappear in storage. It was estimated that it might grade No. 3, where the unaffected wheat graded No. 2. Since, however, the infestation of the field was only 15%, it was not considered that the grade for the entire field had been appreciably lowered. The weight of the two samples was almost identical. It is, of course, possible that the flies had infested only the best developed stems and that the loss was greater than was indicated but field observations failed to indicate that this was so.

As stated above, the straws bend over at the second or third node from the base. This is unfortunately high for all of them to be cut by a binder which is set to cut about 4" from the ground. In several fields examined, no stunted heads could be found after the binder has passed. The loss so

the farmers appears, therefore, to have been negligible from the activities of both generations of the Hessian Fly

It would be unwise, however, to assume that this would always be the case. Poor growing conditions in the spring might result in the death of many seedlings as a result of attack by the first generation and, in a severely affected field, or in one with a thin stand, many heads of stems infested by the second generation might fall right to the ground or at least, to below the cutting bar of the binder In either case they would be a total loss.

Control Measures.

1. Since practically all of the "flax-seeds" from the second generation are picked up by the binder, all of them will find their way to the straw pile and the screenings. All which are fed to stock will be destroyed.

2. Stock can be allowed to feed around the straw piles during the winter, but any straw which is left should be burned before the beginning of May.

3 Straw from infested fields should not be used for bedding-down stock.

4. Burning-over stubble immediately after harvest should destroy any flax-seeds which are on the surface of the ground, but will not affect those of the first generation which may still be in the stubble. It is probably better to cut close to the ground in order to pick up all heads from infested straws even though this reduces the possibility of getting a good burn.

5 If you intend to plough infested wheat stubble before re-seeding to any crop in the following spring, do so before the end of April in order to bury any flax-seeds which may be on the surface or in the stubble. Make sure that you bury all trash.

Notes—In the districts in which Hessian Fly has occurred in Alberta, the Wheat-stem Sawfly also is a source of serious loss in certain years. Unless the Hessian Fly becomes a more serious menace than it has been up to the present, it is suggested that shallow fall cultivation of wheat stubble be maintained in order to reduce the Sawfly and that any deep ploughing be deferred until the spring Such spring ploughing should be followed, when possible, with a packer

6. Cultivate all fallow following wheat frequently up till the end of June in order to destroy all volunteer growth and, with it, any first generation Hessian Fly grubs which it may contain.

7 In the United States, where the second generation of the Hessian Fly is frequently the most destructive pest from which fall wheat suffers, the almost universally employed control measure is to delay seeding until after the flies of this generation have finished laying their eggs. It would appear that damage from the first generation could be avoided in Alberta by taking similar precautions. In 1940, up to 25% damage was observed in all fields which had been seeded before May 10th, while there appeared to be none in any which were seeded after May 17th. The "safe" date

would undoubtedly vary from year to year, and 1940 was, admittedly, a "backward" season.

References to Literature on Hessian Flies

Criddle, N., "The Hessian-fly in the Prairie Provinces" Dept of Agriculture, Ottawa. Pamphlet No. 30, New Series.

SAY'S GRAIN BUG (Chlorochroa sayi).

FIG. 12—Say's Grain Bug.—A Five eggs laid on piece of old stubble, B Half-grown black and yellow bug, C Mature bug, which is green; D. False chinch bug. All figures natural size. (Original)

Distribution. At present this bug appears to be confined to the wheat producing belt to the south and east of Calgary It is most prevalent to the south of the South Saskatchewan River, where appreciable losses have occurred. A few specimens have, however, been found to as far north as Camrose.

History in Alberta and Food Plants. From the earliest days of wheat production in Alberta, a few large green bugs have been observed in grain fields. In 1935, they were found in greatly increased number in southern Alberta and to be causing serious damage to wheat

It cannot, as yet, be stated with absolute certainty whether this is due to a migration from further south, and one which is liable to continue to extend northward, or whether it is due to a marked increase in the population of bugs which are native to this province If it be the latter, this may, possibly, constitute a temporary "outbreak" somewhat similar to that of the Bertha Armyworm which ravaged a large area of the prairie from about 1926 to 1932, and then practically disappeared.

Since 1935, this bug has caused appreciable losses, annually It is most destructive to wheat, but will also attack barley, rye and oats.

Life-history and habits The life-history of this bug has been studied by Mr L A. Jacobson, of the Dominion Entomological Laboratory at Lethbridge. It is as follows:

The large green bugs pass the winter in hiding under rubbish on the ground, such as dead weeds or trash mulch, and in tufts of native grass. Early in the spring they resume activity and the females lay their eggs, chiefly on the underside of the rubbish, where they have passed the winter. The young, wingless, bugs are largely black, with a few yellow marks, but they gradually assume a green colour as they mature. These feed, at first, on young Russian thistle and other weeds but, when they are about half-grown, they may begin to climb to heads of wheat and to feed there.

The mature green bugs feed, almost entirely, on grain. They fly freely from field to field. There are at least two generations a year.

Damage The bugs feed by sucking the contents from the developing grain. This may result in the head turning a rather pale colour before the unaffected heads ripen but, more often, no damage is observed unless the attacked heads be squeezed between the fingers, when they are found to contain little or no grain. Often no damage is suspected until after the grain has been threshed and has been found to yield far less than was anticipated.

Control The only control measure which can be recommended at present is "the early spring burning of weeds and rubbish, under which the adults pass the winter" Jacobson also states that "cropping practice, adjusted by dates of seeding, appears to be of no value in controlling losses"

Reference to Literature on Say's Grain Bug.

Jacobson, L. A. "Say's Grain Bug in Western Canada" P.C.I.I., No. 267, Division of Entomology, Ottawa.

GRAIN THRIPS (Anaphothrips striatus).

Distribution. Entire province.

Life-history and habits. Thrips are minute, slender insects about 1/16" long. They are so small that they are rarely seen. If a dandelion flower be tapped on the hand it is probable that a few of them, which are thus dislodged, will be seen running across the hand. They are quite strong fliers.

Grain thrips pass the winter in stubble, in grass along the headlands and among weeds. Early in the spring they lay minute eggs in small slits cut in the leaves of grasses. Small wingless thrips hatch from these and feed on the young growth of grass. By about the end of June these thrips are full-grown and have developed wings. The females leave the grass and many fly to grain. Here, also, they lay eggs in small slits cut in the upper blades.

The young thrips which hatch from them enter the "boot" and feed on the developing grain flowers. They will not feed on any flowers that are already exposed at this time, but only on those that are still protected by the sheath.

Damage to grain. Oats suffer more than do other grain crops. "Blind" oats, i.e., oat flowers that turn prematurely white and which contain no seed, are produced by a variety of different causes. When they are scattered throughout the heads of oats their presence is not due to insect damage. Blind oats which are confined to the base of the head are, however, often caused by thrips.

In order to make certain whether thrips are present in sufficient numbers to have caused the trouble, gather a few of the upper blades from injured plants. Hold them to the light. Small transparent areas, like pinpoints, indicate places where thrips have laid their eggs. Tear open the

upper leaf-sheath to expose the flowering stem down to the top node. If thrips are abundant it is probable that a few dead specimens will be found within the sheath.

Control. Since grain heads that are fully exposed by the end of June are not attacked, only late seeded oats and barley are liable to suffer from thrips injury. Early seeding of rapidly maturing varieties will largely overcome the trouble in badly infested fields.

Fall ploughing or fall stubble burning, with the destruction of rank growth of grass along the headlands, will destroy many of the hibernating thrips. They are active so early in the spring that spring operations are of comparatively little value.

FALSE CHINCH BUG (Nysius ericae).

Distribution. Entire province. Most prevalent where mustard grows in profusion.

Life-history and habits. These bugs are only about 1/8" long, and they closely resemble Chinch bugs, for which they are sometimes mistaken. (See Fig. 12, page 52.) The true chinch bug does not occur in Alberta, and it has a white area over the greater part of the hinder end of the body. This is missing in the false chinch bug, which is almost uniformly greyish-brown.

Winter is passed by the full-grown bugs which hide under dead vegetation. In the spring they resume activity and, with their hollow needle-like mouths, they suck sap from practically all types of plants. They lay their eggs on the plants on which they are feeding. From these hatch small bugs which are similar in appearance to their parents, though they will remain wingless till they are full-grown. There are several generations in a year.

Damage to grain. False chinch bugs increase rapidly in numbers in fields that have grown up to mustard and some other weeds. When such fields have been cleaned up and seeded in the spring, the bugs which have passed the winter successfully attack the grain seedlings and suck sap from their blades. Each feeding puncture turns red, and the portion of the leaf beyond it may become a sickly yellow. If mustard seedlings now appear in fairly large numbers, nearly all of the bugs will leave the wheat and feed on them. In any case, the damage is not severe, though the plants are set back to a greater or less extent. Later in the season, when mustard is mature and is dying off, many bugs return to the grain and feed on the flowering stem and on the outside of the leaf-sheaths. They produce a blistered, rust-like effect by so doing.

Control. Keep summerfallow clean. There will then be no weeds on which the bugs can increase in numbers.

Plough-in weedy stubble in the fall, or burn off early in the spring. Since the bugs are quite active at the usual time of spring ploughing this will not make a thorough job of burying them, though it is preferable to cultivation.

GRAIN APHIS (Macrosiphum granarium).

Distribution. Entire province. Frequently extremely numerous.

Life-history and habits. Occasionally the heads of all grain crops are found to be swarming with small wingless orange or green plant-lice or Aphids. Scattered among them will be a few individuals that are darker in colour, and which possess transparent wings.

It is not known how these plant-lice pass the winter in Alberta. It is possible that they are unable to do so here, and that infestations are the result of a few flying aphids which migrate into the province from farther south early in the summer.

Plant-lice can increase in numbers more rapidly than can any other insect. Generation follows generation rapidly throughout the summer. All remain wingless unless they have become so numerous on a single plant that they are seriously overcrowded. Whenever this occurs a few winged specimens appear. These fly to and infest new plants. They feed by sucking sap from the heads and from the stems of plants.

Damage to grain. However abundant the plant-lice may be, they do surprisingly little damage. We have seen a field of oats in which the lice were so numerous at harvest-time that the binder was literally gummed up with their crushed bodies. This field yielded 110 bushels per acre! A field of wheat, similarly infested, yielded 34 bushels of No. 1 grain.

The chief damage, therefore, is in rendering harvesting operations disagreeable.

Control. Nothing practical can be done to prevent infestations or to reduce the plant-lice present in grain. We have never known them to occur for two years in succession in the same district.

LEATHER JACKETS (Tipula Spp., etc.).

Distribution. Entire province. Abundant only in damp locations and in irrigated fields.

Life-history and habits. Leather jackets are the larvae of the extremely long-legged flies known as Crane-flies, or "Daddy long-legs." They somewhat resemble dull brown cutworms with no legs or heads.

Although they feed on the roots of grains and grasses, they are never present in sufficient numbers to cause appreciable damage to grain.

MARCH FLIES (Bibio albipennis).

Distribution. Entire province. Abundant only where much decaying vegetation is present, such as in comparatively new breaking or in heavily manured fields.

Life-history and habits. Occasionally, when seed-beds are being prepared in the spring, the ground is found to be swarming with dull brown grubs, about ½" long, which, on close examination, are found to be covered with fleshy spurs somewhat resembling rose- thorns. They are full-grown at this season, and very soon will pupate beneath the surface

of the soil. Later they mature into flies which somewhat resemble large, clumsy mosquitoes.

Since these grubs feed only on decaying vegetation, they are quite harmless to grain.

BEET WEBWORM (Loxostege sticticalis).

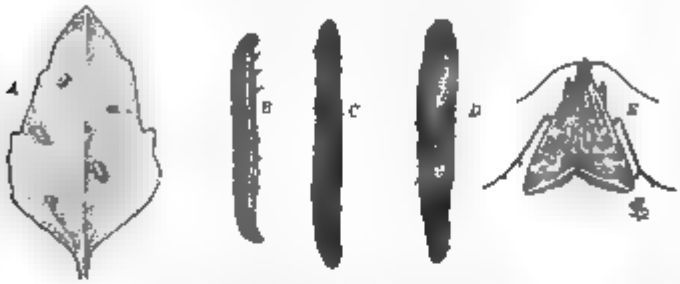

FIG. 13—Beet Webworm:—A Eggs, laid on under side of Lambs-quarters leaf; B Full-grown Beet Webworm (Green with black marks), C Cocoon dug from the soil, D Cocoon opened to show Pupa: E Adult moth (Light yellowish brown) All figures natural size (Original.)

Distribution Entire province Liable to be extremely abundant in every district.

Life-history and habits Beet webworms are the caterpillars of small light-coloured moths which are about ¾" long and of rather slender build. These moths occasionally fly in dense swarms along the side of roads in May and June and again in August They lay nearly all of their eggs on lambs-quarters. From these eggs hatch green-and-black caterpillars which feed on the weeds. When too many eggs have been laid on the same plants the caterpillars devour them completely, and then move across the ground in dense armies in search of more food Once they have chosen their "line of march" nothing will deter them They will climb up houses, over the roof and down the other side, if these happen to be in their way At this time they feed on a great variety of different plants but, generally speaking, *will not touch grain* A somewhat rare exception to this occurs when a large army is passing through a field of wheat in which the heads are just exposed. Under these circumstances a few of the caterpillars will ascend the plants and eat some of the developing flowers from the wheat heads. Despite this unfortunate habit, webworms that pass through a field of wheat do far more good than harm They destroy every weed that they encounter When the caterpillars are full-grown, they enter the soil and there make long earth-covered cocoons of white silk. In these they transform to the moths.

As a rule there are two generations of beet webworms in a year Migrating swarms of caterpillars may be seen towards the end of June and again in early September Under certain climatic conditions, however, the first generation only is completed. The winter is passed in the cocoons,

which may be turned up in large numbers when a field that was weedy during the previous summer is being cultivated in the spring.

Control. No control measures are necessary when these caterpillars are found in grain fields. They are doing far more good than harm.

Fields of beets, sunflowers or flax may be protected from invasion with furrows baited with lambs-quarters (see page 24), or with cutworm bait (see page 24) When they are already present in such fields spraying with Paris green will give satisfactory results provided the weather remains dry This poison is, unfortunately, readily washed off sprayed plants with rain. In recent years, it has been found that more certain results can be obtained from spraying or dusting with poisons made from Pyrethrum. This poison has the advantages of killing the webworms almost as soon as it comes into contact with their bodies and in being non-poisonous to man or livestock A very convenient dust, of which Pyrethrum is the base, is sold in Alberta, under the trade-name of Pyrocide. Other, equally effective, brands are available.

References to Literature on Beet Webworms.

Strickland, E. H., and Criddle, N., "The Beet Webworm," Division of Entomology, Ottawa. Circular 14, 1932

DIAMOND BACKED MOTH (Plutella maculipennis).

Distribution. Entire province.

Life-history and habits. Occasionally, at harvest time, heads of wheat are found to be carrying small lace-like cocoons through which can be seen a small caterpillar or chrysalis. The cocoons are about the same length as a grain of wheat These are quite harmless to the wheat. The green caterpillars of the diamond backed moth feed on mustard and a few other weeds. When they are full-grown many of them leave the plants on which they have fed and climb neighbouring stems of wheat, on the heads of which they spin their cocoons. They never feed on the wheat, and have done more good than harm by destroying a small amount of the weeds.